Biopriming techniques for better germination and seedling growth of sandal (*Santalum album* L.)

By

ANJALI K.S. (2018-17-006)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled "Biopriming techniques for better germination and seedling growth of sandal (*Santalum album* L.)"is a bonafide record of research done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Biopriming techniques for better germination and seedling growth of sandal (*Santalum album* L.)" is a record of research work done independently by **Ms. Anjali K.S. (2018-17-006)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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INTRODUCTION

Priming is the controlled hydration technique in which the seed metabolic activity is enhanced, but suspended prior to radicle protrusion. During priming, a specific physiological state is induced in plants using natural and/or synthetic compounds to the seeds before germination. The priming is normally carried out in liquid and solid particulate systems, and also includes the controlled hydration. The liquid systems manipulate the water potential of

the priming solution with large molecular weight compounds like polyethylene glycol or inorganic salts. In solid particulate systems, seeds are mixed with a solid particulate material such as fine-grade vermiculite and water. Controlled hydration is the addition of a known amount of water to a seed sample of known weight and initial seed moisture content. All priming techniques rely on the controlled uptake of water to achieve a critical moisture content that will activate metabolic activity in a controlled environment.

The various priming agents used includes water (hydropriming) or Poly Ethylene Glycol (PEG) (osmopriming) or salt ($CaCl_2$, $CaSO_4$ or NaCl, etc.) or another chemical or living bacterial inoculums (biopriming) prior to germination. The seeds on priming are benefitted by faster emergence, higher status quo, decreased incidence of re-sowing, more vigorous growth of the seedlings, better drought tolerance, and earlier flowering, harvest and better yield. Research on the physiological and biochemical aspects of primed seeds indicated that protein synthesis is increased by using osmotic conditioning, which might be due to the elimination of stress inhibiting factors such as abscisic acid. The mobilization of the reserve food materials within the seeds may be attributed to the improvement in germination and vigour potential through osmotic conditioning.

Seed priming with living bacterial inoculum is known as biopriming, which involves the application of plant growth promoting rhizobacteria resulting in enhanced germination, plant growth and disease résistance. In addition, it ameliorates a wide variety of biotic, abiotic, and physiological stresses to seeds and seedlings. Biopriming agents include useful microorganisms like fungi and bacteria e.g. *Trichoderma, Pseudomonas, Bacillus, Rhizobia* etc. Biopriming also offers an opportunity to replace the use of chemicals to control pests and diseases. During biopriming, the bacteria enter/adhere the seeds and acclimatize under familiar conditions. Plant growth promoting rhizobacteria (PGPR) are a wide range of root colonizing microorganisms that can produce Indole-3-acetic acid (IAA) like, compounds (Kandoliya and Vakharia, 2013), which improves plant growth *via* improved seed emergence period, plant growth and crop yield. Seed priming has additionally proven to be successful in lowering the germination time and uniform seedling germination of few vital tree species.

Sandalwood is the aromatic heartwood of species of genus Santalum (family “Santalaceae). Santalaceae includes approximately 36 genera and more than 400 species of semiparasitic shrubs, herbs, and trees. The essential oil from this wood occupies significant place in perfumery industries. In India, the Santalum genus is represented by *Santalum album*

L commercially recognized as East Indian Sandalwood. The oil obtained East Indian Sandalwood is one of the oldest recognised perfumery materials. Sandal is a small to medium sized evergreen tree reaching a height of 12 to 15 meters and a girth of 2.0 to 2.4 meters with prolific branching and narrow drooping leaves. In India, *Santalum album* is observed throughout out the country, with over 90% of its stock in Karnataka and Tamil Nadu which account for approximately 9600 km^2. It also occurs in Andhra Pradesh, Kerala, Maharashtra, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh, Bihar and Manipur. The tree flourishes from sea level to 1800 m altitude in different forms of soils like sandy, clayey crimson soils, lateritic, loamy or even in black cotton soils. Trees growing on stony or gravelly soils are characterised by extraordinarily scented timber. It grows in high-quality where there is moderate rainfall of 600 to 1600 mm.

The high price of the sandal timber in the global market has resulted in the illegal felling of trees in their natural habitat. India enjoyed the monopoly of sandalwood trade, producing more than 80 per cent of the world's sandalwood and oil, and nowadays, annually produces approximately 400 tons from *Santalum album*. Illegal trading of the sandal is pervasive. In addition, sandal in India is facing heavy loss from the spike disease. All these elements have led to the categorization of ˜Vulnerable in line with the IUCN listing, 2010, after its production has diminished up to 80 per cent within the three decades. An expected range of one lakh above trees in Marayur from the report by Varghese (1976) has been recently updated as about sixty thousand trees in the protected region. The economically viable sandal population are reported be to be commercially extinct due to illegal harvesting and over exploitation. Hence, there is dare need to regenerate and conserve the species in its natural habitat as well to raise plantations. The bottlenecks in raising large-scale sandal plantations are the low germination rate of the seeds, longer germination duration and slow rate of seedling establishment in the field. Fruit is a drupe and the hard seed coat makes the seed difficult to germinate. Artificial propagation methods have not been successful in sandal, hitherto. Therefore, new techniques to improve the germination and uniform growth of the seedlings of sandal must be achieved for the production of high quality planting stock. The germination in sandal is sporadic and completes within a duration of 4 to 12 weeks). Prolonged nursery period is a major hurdle in raising high-quality planting stock of sandal. Among the various pre-treatments tried in sandal seeds, soaking the seeds gibberellic acid 500 ppm was identified as the best. The study conducted at College of Forestry by Chitra (2019) on the Impact of seed priming techniques on the germination and seedling attributes of

sandal with higher concentrations and durations of priming agents like water, MnSO4, PEG 6000 and *Pseudomonas fluorescens* indicated that higher duration of treatment and post-priming storage for one day was the best in terms of germination and seedling attributes, but the post priming storage of seeds for one month could not initiate germination. Moreover, the biopriming treatment was superior to other priming methods. Hence, the present investigation focuses on biopriming with three agents at lower concentration and duration and a lower post priming storage of one week.

Pseudomonas fluorescens is an aerobic, gram-negative, omnipresent bacteria present in agricultural soils and well adapted to grow in the rhizosphere. This Rhizobacteria act as a biocontrol agent and to promote the plant growth ability. *Trichoderma viride* is a fungus well known for its antagonistic ability towards plant pathogenic fungi and they also have received considerable attention as biocontrol agent of soil-borne plant pathogens. PGPR II is a consortium of highly compatible rhizobacteria viz. *Bacillus subtilis* and *Pseudomonas fluorescens* having broad spectrum of inhibitory property with different mechanisms. The present investigation was formulated with the following objective, keeping the above aspects in view.

- To evaluate the effect of three biopriming agents viz. *Pseudomonas fluorescens*, plant growth promoting Rhizobacteria (PGPR II) and *Trichoderma viride* on the germination and seedling growth of sandal (*Santalum album* L.*)*

REVIEW OF LITERATURE

Sandal (*Santalum album*, L) is one of the esteemed and high–priced timber species of the world. It has attained great importance in the global market due to its fragrant heartwood and volatile oil. In India, sandalwood tree is marginally distributed in the Deccan plateau and the total sandal area is 9600 km^2 of which 8200 km^2 occurs in Karnataka and Tamil Nadu (Srinivasan *et al*., 1992). Ecologically sandal is acclimatized to various soil and agro-climatic conditions for *in situ* regeneration but did not prefer waterlogged and very cold areas. Regarding the wood characters, the sandal sapwood is white to pale yellow in colour, which is distinct from yellowish brown to dark brown heartwood, heavy, lustrous, hard and straight-grained to slightly wavy and fine textured with pleasant characteristic smell (Rao and Srimathi, 1976). In Kerala, sandal is sporadically distributed in the deciduous forests up to an elevation of 900 m; it is common at Marayur. The estimates indicate that the worldwide demand for sandalwood is about 5000-

6000 tons year^{-1}, which of oil is 100 tons year^{-1} (Joshi and Arunkumar, 2007). This demand is predicted to skyrocket in the coming years and in India, sandalwood production is greatly reduced which is evident from the data that the sandalwood production has declined from 1500 tons year^{-1} in 1997-98 to 500 tons year^{-1} in 2007 and 100 tons year^{-1} in 2011-12. Sandal heartwood prices have increased from Rs. 365 ton^{-1} in 1900 to Rs. 6.5 lakhs ton^{-1} in the year 1999-2000 and to Rs. 37 lakhs ton^{-1} in 2007 (Joshi and Arunkumar, 2007). Because of the extensive changes in the land use patterns, habitat destruction and indiscriminate exploitation of the sandal resources for generations, the natural stock of the species has been rapidly dwindling in the country (Arunkumar *et al.,* 2010). Considerable decline in the natural populations of sandal due to illicit felling and over exploitation has resulted in the categorization of the species as 'Vulnerable' to extinction within the IUCN red list (IUCN, 2010). Hence, the regeneration of sandal is of great challenge and a priority to the forest department. The poor rate of germination of sandal seeds along with the prolonged period of germination are the main constrains in the regeneration of sandal.

2.1 Seed germination in sandal

Sandal fruit type is drupe, globose, 1.25 cm in diameter, purplish-black, with hard-ribbed endocarp. Seeds are globose (Luna, 1996) and 0.2 to 1.2 cm in diameter (Srimathi *et al.,* 1995) and 6000 to 7055 seeds per one kg (Sengupta, 1937; Kumar and Bhanja, 1992). Nagaveni and Ananthapadmanabha (1986) had graded the seeds of sandal into small, medium and large classes based on the seed size and weight and reported that around 82 to 87% of the sandal seed lot falls in to medium category, weighing 0.1 to 0.2 g and a mean size of 7 to 8 mm. In general, sandal seeds when dispersed by birds within the natural habitat require four to eight weeks to initiate the germination (Venkatesh, 1995). Srimathi *et al.,* (1995) stated that sandal seeds exhibit sporadic germination and the complete germination occurs within a period of 4 to 12 weeks only. The dormancy of the seeds plays a major role in the regeneration of sandal. However, exact mechanism of the dormancy is not known yet. For instance, Baskin and Baskin (1988) reported that the sandal seeds have physiological or morpho-physiological dormancy i.e. the dormant embryo in the seeds should elongate inside the seed prior to, during or after the loss of dormancy. Based on these facts, they inferred that the sandal seeds are to be subjected to (1) warm stratification for removal of dormancy (Srimathi and Rao, 1969) and (2) it has a prolonged germination period (Beniwal and Singh, 1989). Sandal seed embryos are very minute (Rangaswamy and Rao, 1963), but whether or not they develop prior to radicle elongation is not known. Subsidiary information suggest that the sandal seeds dormant at maturity and possess physiological component in the dormancy: germination boosts with (1) gibberlic acid (GA_3) (Nagaveni and Srimathi, 1980; Cromer and Woodall, 2007; Nikam and Barmukh, 2009; Gamage *et al.,* 2010) and (2) with removal of the fruit coat since the embryo possess low growth potential (Loveys and Jusaitis, 1994; Woodall, 2004; Cromer and Woodall, 2007). Clarke and Doran (2012) suggested that the sandal seeds have an exogenous type of dormancy because of the factors outside embryo. Das and Tah (2013) opined that enforced dormancy of sandal seed is probably because of chemical inhibitors within the testa which is impermeable to water and gases. However, Prasetyaningtyas (2007) has opined that the sandal fruit pulp seems to have some chemical inhibitors which is evident from the fact that when the seeds are extracted, they do not show dormancy.

Among the several pre-germination treatments like cow dung soaking, acid scarification and gibberellic acid application (GA_3) in sandal seeds, soaking the seeds in GA_3 0.05% solution emerged as the best pretreatment. The pretreatment at 0.05% GA_3 has resulted in 35 to 45 per cent germination (Sudhir *et al.,* 2013). The rationale for the prevalence of GA3 treatment can be traced to several GA signalling factors like, the expression of genes that produce enzymes which mobilize stored food reserves within the endosperm such as proteins, starches and lipids,(Peng and Harberd, 2002). Nagaveni *et al.* (1989) tried various pre-treatments like soaking in water $ZnCl_2$, NaOH, IBA, cytozyme, thiourea, IAA, HCl or a methanolic extract of fresh sandal leaves, H_2O_2 and kinetin and found that each one of the treatments increased the speed of germination compared to control, and the imbibition period was reduced from 60 to 15-45 days. An early and rapid germination within 15 days was reported after breaking the false seed coat, indicating the presence of inhibitory chemicals within the testa (Srimathi and Rao., 1969). Treating sandal seeds with dilute NaOH HCl or GA_3 are reported to eliminate the inhibitory chemicals from the seed (Ananthapadmanabha *et al.* 1988); soaking seeds in GA_3 500 mg l^{-1} for 16 h could improve germination up to 60% in the field conditions (Nagaveni *et al*., 1989). Sutheesh *et al.*, (2016) confirmed that treating with GA_3 is the best treatment to enhance germination in sandal. However, some organic pretreatments like keeping in cow dung slurry and urine also can increase the germination. The sulphuric acid and boiling water treatments reduced the germination of the seeds compared to control. Sutheesh *et al*. (2016) stated that poor rate of germination related to long germination period of 140 – 150 days is the major constraint in obtaining the regeneration of sandal.

2.2 Constraints in regeneration sandal

Natural regeneration of sandal occurs through seeds and root suckers. The seed dispersal is normally through birds and these seeds normally take 4 to 8 weeks initiate germination (Venkatesan, 1995). Normally, the seeds retain the viability for one year and reported to have post dormancy period of 2 months because of the impermeable testa. Sand is the most common rooting media used for germination of sandal seeds. As a prophylactic measure, the germination media in trays should be treated with nematicide and fungicide, periodically. The pretreated seeds are sown in germination trays filled with vermiculite or sand and soil in 1:2 ratio.

Artificial regeneration in sandal is commonly achieved by dibbling seeds in pits or sowing the seeds on mounds and trenching around mother trees for wounding the roots for root sucker induction. Use of nursery raised, vegetatively propagated and micropropagated and seedlings are common (Rai and Kulkarni, 1986). Vegetative propagation is accomplished through stem cuttings, grafting, and air layering or through root suckers. The rooting of stem cuttings is poor i.e. 15- 20 % (Rao and Srimathi, 1976; Uniyal *et al.,* 1985; Balasundaram, 1998; Sanjaya *et al.*, 1998). Micropropagation through the axillary shoot proliferation, somatic embryogenesis and adventitious shoot induction (Bapat *et al.,* 1990; Bapat and Rao, 1999; Gairola *et al.,* 2007). There is severe decline in the natural sandal population of sandal, because of the factors like recurring annual fires within the natural habitats, excessive grazing, illicit felling and spreading of spike disease etc. which are further accelerated by the manmade activities (Venkatesh and Srimathi, 1981). The decreasing rate of sandal population also can be attributed to the poor germination rate of seeds, over-exploitation and failure of natural as well as artificial regeneration

(Jeeva *et al.,* 1998). The freshly collected sandal seeds shows after-ripening for a period of 60 days after which the seeds attain physiological maturity (Srivasan *et al.,* 1992). The sandal seedlings at nursery stage is vulnerable to diseases and pests. The main pathogens infecting the seedlings causing severe economic loss in nurseries were Rhizoctonia, Phytophthora, Pythium and *Fusarium oxysporum* (Rathore, 2007). The poor regeneration in sandal also can be attributed to the low seed setting and lack of seedling vigour. Exploitation of the great quality trees at a faster rate furthered by illicit felling has led to a severe decline in population which resulted in the fragmentation of the population leaving inferior trees (Balasundaram, 2010). The cumulative seedling death rate of sandal in Nachivayal reserve forest in Marayur was reported to be 94.5% at 2 years after the emergence of the seedlings sown in mounds (Balasundaram, 2010).

2.3 Seed Priming

Seed priming is one among the key technologies to achieve seed enhancement through rapid germination of seeds and optimizing the seedling establishment after planting in the field. It is a controlled seed hydration treatment during which the metabolic activity is enhanced, but suspended before radicle protrusion. Different priming treatments includes, soaking seeds in water (hydropriming) or PEG (osmopriming) or salt ($CaCl_2$, $CaSO_4$ or NaCl etc.) or the other chemicals and biological agents (biopriming) prior to germination. Priming inducts a specific physiological condition in plants through the treatment of priming agents. The efficiency of seed priming depends on many factors and is strongly depend on the plant species and therefore the method of priming varies. The success of priming depend on physico-chemical factors like osmoticum and water potential, priming agent, duration of treatment, light, temperature, aeration and the seed condition (Hussain *et al.*, 2006, Varier *et al.*, 2010).

Nowadays, seed priming is a commercially used simple and efficient process to accelerate the seed germination and to improve seedling uniformity in many crops (Halmer, 2003; Taylor and Harman, 1990). Additionally, plants can gain resistance to abiotic stress after treatment with several natural or synthetic compounds like Butenolide, Selenium, $CuSO_4$, $ZnSO_4$, KH_2PO_4, ethanol, Putrescine, Paclobutrazol, Choline, and Chitosan (Demir *et al*., 2012). The increased germination rate and uniformity of germination achieved through priming are often attributed to metabolic repair occurring during imbibition (Burgass and Powell, 1984) or could due to the buildup of germination enhancing metabolites (Basra *et al.,* 2005). Priming augments the events preceding the germination, but the entire germination process is interrupted at a given state. It also induces structural and ultra-structural modifications that would ease the subsequent water imbibition and attenuate initial variation among the seeds in rate of imbibition leading to a more uniform germination. Once the priming conditions are withdrawn, the seed germination is typically faster and more uniform. Nonetheless, the particular cellular events happening during seed priming greatly remains uncertain.

The reduction in leakage of metabolites (Styer and Cantliffe, 1983), rise in synthesis ribonucleic acid and protein (Fu *et al.,* 1988), the expression of β-tubulin (De Castro *et al.,* 1995) and nuclear DNA synthesis within the radicle cells of seeds (Saracco *et al.,* 1995; Liu *et al.,* 1997), faster embryo growth (Dahal *et al.,* 1990), nuclear replication (Lanteri *et al.,* 1993&1996), and minimal chromosomal damage

(Sivritepe and Dourado, 1995) are promoting effectors of seed priming. Priming is reported to initiate the repair and reactivation of pre-existing mitochondria and to initiate the biogenesis of latest ones (Sun *et al.,* 2011). It is going to thus afford a better level of energy over a brief time to sustain final germination (Nascimento, 2013). The increase in germination by priming could also be related to a change in phytohormone biosynthesis and signaling. Priming has increased gibberellins /abscisic acid ratio (El-Araby *et al.,* 2006), and this might cause direct effect on a priming impact in organic phenomenon pattern (Schwember and Bradford, 2010). A more uniform endogenous GA concentration may help to synchronize endosperm weakening, embryo cell elongation, and reserve mobilization (Sung *et al.,* 2008). Ethylene may directly influences speed and rate of germination. Seed priming, commonly synchronize individual seed germination (Taylor and Harman, 1990). In addition, seed priming give abiotic stress tolerance to plants (Ashraf and Foolad, 2005; Patade *et al.,* 2009).

Seed priming benefits mainly from the activation of enzymes related to endosperm utilization (Habib *et al.,* 2010), mobilization of storage proteins and changes in hormonal balance (Iqbal and Ashraf, 2013). Moreover, seed priming aids to synthesize proteins that play crucial role during germination in several plant species (Gallardo *et al.,* 2001). Furthermore, the rapid and uniform germination through seed priming also can be attributed to stimulation of antioxidant activities (Chiu *et al.,* 2002; Afzal *et al.,* 2012). Re-drying of the seeds to their original moisture content, following seed priming is an inevitable step which can otherwise do harm to the primed seeds (Thomas *et al.,* 2000) thereby affecting the seed quality (Parera and Cantliffe, 1992). Improper seed re-drying may cause reduction in the lag time of imbibition affecting seed germination (Heydecker and Coolbear, 1977; Brocklehurst and Dearman, 1983). Re-drying must be attained slowly to take care of the benefits obtained during priming.

2.3.1 Biopriming

Seed biopriming is one among the foremost suitable techniques for the appliance and subsequent establishment of bacterial antagonists with in the spermospheres and rhizospheres (Zein, 2006). It is considered as a safer, cheaper and simply applicable method for biological control (El-Mougy and Abdel-Kader, 2008). It has potential advantages over seed coating (Muller and Berg, 2008) because of the very fact that biopriming aid in establishing the bacteria within the seed which attributes to the higher stability and time period of the seeds. Beneficial soil microbes and their association greatly influences the plant health and soil fertility (Jeffries *et al.,* 2003). The biopriming which integrates disease control is used recently as an alternative method for controlling many seed and soil borne pathogens (Begum *et al.,* 2010). The concept of sustainable agriculture has given more importance for the utilization of rhizospheric bacteria to assist plants for easy nutrient uptake and solubilisation of fixed nutrients like phosphorus (Hayat *et al.,* 2010). *Trichoderma viride, Trichoderma harziaum* and *Pseudomonas fluorescens* are different bio-control agents frequently used for biopriming treatment. Several scientists have investigated the utilization of beneficial micro-organisms within the priming medium to regulate disease proliferation during priming itself (Warren and Bennet, 2000). There are different methods used for explaining biopriming varying with the temperature and duration for soaking the seeds (Mich´e and Balandreau, 2001; Gholami *et al.* 2009; Abuamsha *et al.* 2011; Sharifi and Khavazi, 2011; Sharifi *et al* .2011; Carrozzi *et al,* 2012; Firuzsalari *et al.* 2012; Saber *et al*.2012; Kasim

et al. 2013; Reddy 2013). Many researchers have also surface disinfected the seeds prior to soaking into the bacterial suspension.

2.3.2 Significance of biopriming in plants

Bio-priming with *Pseudomonas aureofaciens* in sweet corn gave protection against damping-off as good as or better than seed treatment with metalaxyl when the seeds were planted in cold soil (Callan *et al.,* 1990). *Trichoderma* is being used as a bio-control agent against many phyto-pathogenic fungi and *Trichoderma spp* are reported to increase the plant health by improving overall plant growth apart from the direct inhibition of plant pathogens (Fattah *et al.,* 2007). Soil application of Trichoderma enriched Farm Yard Manure was most effective in controlling the seed borne pathogenic fungi *R. solani, F. moniliforme, F. oxysporum, F. solani, A. alternata* and *B. theobromae* (Mustafa, 2009). Plant growth promoting rhizobacteria (PGPR) accelerates the assembly of phytohormones (Indole Ethanoicacid, gibberellins and cytokinins), by siderophore production increase the mineral phosphate solubility and reduce the assembly of abscisic acid during stress (Rai *et al.,* 2014). There was the induction of systemic stress tolerance in plants, by adjusting metabolic processes on colonization of PGPR, *P. fluorescens*, (Saakre *et al.,* 2017). PGPR helps in various aspects of development and functioning of the plants. (Vacheron *et al.,* 2013) like the expanding the supporting rootage (Pérez-Montaño *et al.,* 2014), nitrogen, phosphorus and iron nourishment (Richardson *et al*., 2009), functioning of photosystem (Samaniego-Gámez *et al.,* 2016) and protection to stresses like drought (Vurukonda *et al.,* 2016), cold (Kakar *et al.,* 2016) and pathogen (Beneduzi *et al.,* 2012). Seed inoculation with bio-agents along with priming has been reported to strengthen and stabilize the efficacy of biological agents (Callan *et al*., 1990&1991; Harman *et al*., 1989; Warren and Bennett, 1999).

Biopriming using PGPR is reported to improve the germination of chickpea (*Cicer arietinum* L) seeds under saline stress and also resulted an increment shoot and root parameters and biomass production of the seedlings (Mishra *et al.,* 2010). An improvement of sprouting on treating with several genera of PGPR like *Pseudomonas, Azospirillum and Bradyrhizobium* is reported by several workers (Raj *et al.,* 2004; Cassán *et al.,* 2009; Kaya *et al.,* 2006; Nezarat and Gholami, 2009; Noumavo *et al.,* 2013; Rozier *et al.,* 2017). Bacterial inoculation of the seeds of Maize cultivar led to a 6–8h hastening of radicle emergence, increased surface bacterial counts, lower contents of energetic primary metabolites before radicle emergence and increased photosynthetic yield, and root area, in 3-leaf plantlets. (Rozier *et al.,* 2019). Inoculation of seeds with PGPR has proved to be an elective and eco-friendly agro-engineering practice to extend the sturdiness of food production and limit its ecological impact (Duhamel and Vandenkoornhuyse, 2013; Gupta *et al.,* 2015).

Karthika and Vanangamudi (2013) reported that biopriming with Azospirillum 20% for 12 h in hybrid maize showed significant increase in germination, root and, shoot length, total dry biomass production and the vigour index in comparison to primed seeds and other treatments. Biopriming with 20% Azospirillum for 12 h in maize seeds could impart greater germination (95%) over non-primed seed (70%) and hydroprimed seeds (85%). Treating seeds with phosphobacteria at 20% for 12 hours also could result in higher germination (95%) (Kalaivani, 2010). Zorita and Canigia (2009) bioprimed the wheat seeds with liquid formulation of *A. brasilense* and recorded vigorous seedling growth with increased

shoot and root biomass accumulation. Priming also increased grain yield. In maize, the Azotobacter and Azospirillum strains were used as biopriming agents, and result showed an increase in crop rate, biomass production and grain yield (Sharifi, 2011).

In wheat, seed biopriming with salinity tolerant isolates of *Trichoderma* were successful in improving germination under salinity stress (Rawat *et al.,* 2011). Priming of rice grains with *T. harzianum* isolate WAI-D resulted in the highest seed germination (92%) of vigour index of 944.84 which was significantly higher over other treatments and nonetheless *Trichoderma viride* isolate CHK-I has shown good performance with average germination of 86.33% and seedling vigour index of 661.28 and therefore the least germination were observed in the control (Devi *et al*., 2019). Biopriming *Phaseolus vulgaris.* L seeds with *Trichoderma harzianum* for 4 h improved germination (78%), shoot length (50.2 cm), seedling dry biomass (2.25 g), seedling vigour index of 3889.6, and speed of germination (9.2) (MonaLisa *et al*., 2017). Biopriming with strains of *Trichoderma viride, T. harzianum, B. subtilis* and *Pseudomoans fluorescens* has resulted in the reduction of disease incidence compared to control (El-Mougy and Abdel-Kader (2008) and the disease incidence was significantly in pre – emergence stage that the post – emergence stage. Nayaka *et al*. (2010) has reported that *T. harzianum* application has resulted in the btter control of *F. verticillioides* and *fumonisins* in maize.

Sunflower seeds on biopriming with *P. fluorescens* strains improved the germination and increased the seedlings uniformly (Moeinzadeh *et al.,* 2010). Biopriming with *P. fluorescens* in tomato seeds reported to exhibit higher germination, field emergence and reduction in wilt in seedlings (Asha *et al*., 2011). A study conducted in pea seeds by Negi *et al*., (2008) reported that priming by *P. fluorescens* pointed out marked increase in shoot and root dry weight and were effective in enhancing plant growth activities and yield performances in the field. Biopriming with *Azospirillum brasilense* and *P. striata* (20%) greatly increased the seed germination, root and shoot height, dry matter accumulation, vigour index and lower disease occurrence in hybrid maize seed compared to hydropriming and control. Biopriming using co-flocs, (*A. brasilense* MTCC125 and *P. fluorescens* MTCC-4828) strikingly increased the germination and vigour index in rice (Joe and Sivakumar, 2011). Nayaka *et al*. (2009) reported biopriming of maize seeds with pure culture and the formulations of *P. fluorescens* increased the seed germination, seedling height, seedling vigour and yield also as a dwindling rate of incidence of *F. verticilloides* to a greater extent in comparison with control. Raj *et al.,* (2004) concluded that treating seeds with *P. fluorescens* isolates in pearl millets increased the expansion of seedlings and induced the resistance against mildew. The flowering time was advanced by 5 days with a 22 per cent increase in yield of grains and 20 to 75 per cent immunity to false mildew. Biopriming of chickpea seeds of variety JG - 11, with *P. fluorescens*@ 0.8 per cent + *T. harzianum* @ 0.8 % + vermiculite shown the smallest amount percentage seed infection of 13.00 from seed – borne pathogen , highest germination per cent of 91.00 and vigour index of 1753.13 which was statistically superior over other treatments (Jainapur *et al*.2018). Biopriming of bulrush millet seeds with *P. fluorescens* triggered the plant growth by inducing resistance against mildew disease by the fungus *Sclerospora graminicola* (Raj *et al*.2003). Study in safflower to find out effect of *Pseudomonas* priming along with nitrogen application revealed seed priming with Pseudomonas strain 186 with coapplication of 180 kg ha^{-1} increased growth and subsequent grain

yield (Sharifi, 2012). The study by Mariselvam (2012) indicated that biopriming with *P. fluorescens* at 60 per cent for 12 h + foliar spray of *P. fluorescens* at 2 g $l^{-1}$of water resulted in maximum plant growth and development in bhendi on with a mild increase in the amounts of chlorophyll. Karthika and Vanangamudi (2013) studied biopriming of mung and maize hybrid COH (M) 5 seed with liquid biological fertilizers which enhanced germination and vigour index.

2.4 Hydropriming

The seed priming method in which the seeds are soaked in distilled or normal water to initiate the pre-germination activities suspending prior to radicle emergence is named as hydropriming. The seeds after a specific period of hydration are dried back to the original moisture under shade conditions (Mc Donald, 2000) or by induced air under shade (Bennett and Waters, 1987).The seeds after soaking is to be dried because storing of partially dried seeds will results in more harmful effects to the seeds (Thomas *et al*., 2000). Hydropriming is the simplest and easiest among the seed priming techniques since it depends on soaking in pure water and re-drying to original moisture content before sowing.

The protoplasm of seeds subjected hydropriming have a lower viscosity and exhibit increased permeability to water and nutrients and also withstand dehydrating forces (Thomas *et al*., 2000). The advantage of hydropriming is the augmentation of physiological and biochemical processes happening in seeds even when the germination is suspended by low osmotic potential and negligible matric potential of the imbibing medium (Basra *et al*., 2003). Increase in the seedling growth correlated with higher water intake by primed seeds is the main feature of hydropriming (Yagmur and Kaydan 2008). Fujikura *et al*. (1993) reported the hydropriming as an easy and cheap method and consistent with Abebe and Modi (2009), it is a major seed treatment technique for quick germination and uniform seedling establishment. A study in barley by Jaudi and Sharifzadeh (2006) identified that hydropriming can improve rate of germination, length of coleoptile and root, dry mass accumulation and seedling vigour index. It had been observed as the most successful method for improving seed germination in onion (Caseiro *et al*., 2004). However, Filho and Kikuti (2008) reported that even though priming increases the speed of germination and uniformity of seedling emergence in cauliflower yield was not affected. Hydropriming treatment for 48 and 24 hours significantly increased the germination percentage, seedling weight and vigour indices compared to control in *Aegle marmelos* (Singh, 2017).

Hydropriming in chickpea resulted in three to four times increases in root and shoot length to control seedlings in drought condition (Kaur *et al*., 2002) which can be attributed to the faster of roots and shoots resulting in vigorous plants and thus better drought tolerance. (Amzallag *et al*., 1990; Cayuela *et al*., 1996; Lee-suskoon *et al*., 1998). In wheat, hydropriming caused significant improvement in germination and early growth. In wheat, hydropriming was found to be effective in improving the seeding vigour (Jafar *et al*., 2012). Daniel *et al*. (1984) hydroprimed lettuce seed in water at 15°C in the dark for various durations and revealed that the hdropriming for 20 h increased germination up to 86 % in lettuce seeds. Moradi and Younesi (2009) reported that both hydropriming and osmopriming increased the percentage and mean time of emergence in sorghum seeds at sub-optimal temperature of 15°C. Seed

treatment for 12 and 24 h had a positive and significant effect on emergence percentage and rate. Hydro riming for 36 h did not have specific effect on these factors.

Amooaghaie (2011) reported that seedlings from hydroprimed seeds had a higher root and shoot growth compared to the seedlings from control. Li *et al*. (2011) from their laboratory experiment on hydropriming of the seeds of pyrethrum concluded that it has significantly reduced the mean germination time and increased the germination percentage. Consistent with Srivastava *et al*. (2010), hydropriming was the foremost suitable priming technique in mustard. Shah *et al*. (2012) also suggested hydropriming as an efficient seed priming technique for enhancing the vigour and nutrient uptake in mung bean. Similarly, Umair *et al*. (2012) also proved that hydropriming significantly increased the seed yield of mung and also enhanced the antioxidant enzyme activities. Venudevan *et al*. (2013) also presented hydro priming as probably the most cost effective priming method of seed priming. Duration of the hydropriming treatment is decided by controlling the seed imbibition and therefore the hydrated seeds

2.5 Changes in seed biochemicals with biopriming

The priming is associated with the changes in biochemical composition of the seeds. Biopriming of garden pea seeds using *Trichoderma viride* and *Pseudomonas fluorescens* had resulted in an increase in the germination seedling parameter and also as a rise in the chlorophyll content (62.1%) and biochemical parameters like total sugar (31.7%) and total protein (17.2%) (Manjubala, 2015). Podile and Kishore (2006) conclude that PGPR modifies and increased germination of seeds, biomass, carbohydrate accumulation., Kasim *et al*. (2013) enumerated the biopriming effects against drought stress which included increased quantiy of osmolytes like protein, sugar and free amino acids increased the solute concentration in drought exposed plants helping the absorption of water from dry soil (Fahad *et al*., 2017) and *Pseudomonas* sp. can supply certain extracellular polymeric substances present in soil pores and increase water retention capacity of the soil under water deficient condition (Kroener *et al*., 2018).

The storability studies in maize seeds on biopriming with *P. fluorescens* reported that Priming at 80% concentration for 12 h resulted in a rise in germination (11%), root (65%) and shoot (88%) length, dry weight accumulation (38%) and vigour index (83%) over non-primed seeds after a storage period of six months (Kalaivani, 2010). At the sixth month of storage, rice seeds bioprimed with *P. fluorescens* at 60% for 12 h caused significant increment in germination (11%), shoot and root length (14%), dry matter accumulation (19%) and vigour index (12%) over non-primed seed (Kavitha, 2011). Mariselvam (2012) reported that biopriming in bhendi seeds with *P. fluorescens* at 60% for 12 h resulted in an 18% increase in germination compared to control. but the , the quantity biochemical characters like free amino acids and reducing sugars declined compared to the non-primed seeds. Mireshekari *et al.,* (2012) reported a rise of nitrogen and phosphorus levels on seed priming with PGPR and therefore the yield and dry matter accumulation of spring barley (*Hordeum vulgare* L.) were increased. .

2.6 Priming in forest trees seeds

Only limited literature are available on seed priming of forest tree species and the application of priming is mostly limited to various pine species (Haridi, 1985; Hallgren *et al*.1989; Bourgeois *et al.* 1991; Su-juan *et al*. 2012) and inducted the priming techniques like hydropriming and osmopriming.

Biopriming with beneficial micro-organisms comprising of fungi and bacteria (*Trichoderma, Pseudomonas, Bacillus, Rhizobia* etc.) can provide tolerance to the various of biotic, abiotic, and physiological stresses to seed and seedlings (Sharma *et al*. 2015). The bacteria to enters or stick on the seeds and also acclimatization of bacteria within the prevalent conditions occur during biompriming (Mahmood *et al.* 2016). Plant Growth Promoting Rhizobacteria are a group of bacteria colonizing on root which may produce Indoleacetic acid like compounds (Kandoliya and Vakharia, 2013) and enhances seed emergence, plant growth yield (Kloepper, 1992).Biopriming seeds with *Pseudomonas fluorescens* along with hydropriming has shown a rise in the germination up to 91.45% in *A. hickelii* and 68% in *A. religiosa* (Rodriguez *et. al*. 2015). Alwathnani *et al*. (2012) demonstrated the antagonistic effect of *Trichoderma harzianum* and *viride* against *Fusarium oxysporum* as inhibition of radial growth of pathogen.

Adebisi *et al*. (2011) tried hydropriming of the seeds of *Cordia millenni* and which was reported to be successful in increasing the germination percentage and seedling vigour. Hydropriming and chemical priming showed to enhance the very best physiological potential and increased germination performance in *Guazuma ulmifolia* (Tay *et al.* 2010). Osmopriming with 20% PEG increased the germination percentage, mean germination time, vigour index and shoot height in *Gmelina arborea* (Adebisi *et al.* 2013). Venudevan and Srimathi (2013) studied the positive influence of hydropriming in *Aeglemarmelos* and concluded that highest germination and seedling growth attributes were achieved by hydro priming of seeds for 6 hours. Osmopriming in *Azadirachta indica* seeds had induced hydrogen peroxide during germination that could be the signaling molecule for germination improvement (Pandey and Pati, 2016). Chemical priming reduced the imbibition period and improved germination index, seedling diameter, seedling length and dry weight in *Aegle marmelos* (Singh, 2017). Osmopriming of seeds has resulted in lower EC of seeds, higher percentage and speed of germination and higher seedling growth and uniformity. In *Pinus taeda* and *P echinata* pines osmotic priming with polyethylene glycol improved both the total germination and quicknesss of germination (Hallgren, 1989) but it was detrimental in *P. elliottii*. The chemical priming of *Casuarina equisetifolia* seeds increased the germination up to 65% on after soaking in 1.5% KNO3 for 36 h but the higher and lower concentration, as well as shorter soaking duration resulted in a lower germination (Maideen *et al*. 1990).

Murthy and Reddy, (1989) the effect of KNO3, GA_3, thiourea and BA on germination of the *Ziziphus mauritiana*. The results indicated that KNO3 was less effective compared to others in all germination parameters. Thiourea was the most effective germination stimulant for and soaking in a 1% solution for the whole day increased the germination from 41% (control) to 78% at 30°C. Bio priming with *Pseudomonas fluorescens* improved flooding tolerance in Sandal (*Santalum album*) seedlings. (Chitra and Jijeesh, 2019).

Chitra (2019) studied impacts of chemical priming, osmopriming, hydropriming, and biopriming on germination and seedling characteristics of *Santalum album*. The result indicated that that the sandal seeds subjected to biopriming with *Pseudomonas fluorescens* at 100% for 8 days and the seeds subjected to chemical priming with 0.8 M of Manganese sulphate for 3 days recorded the highest germination of 88 per cent among the 52 priming treatment combinations. The germination percent exhibited by the seeds

subjected to chemical priming at 0.4 M, 0.6 M and 1 M of manganese sulphate for 3 days were on par with the germination percentage of seeds subjected to biopriming with Pseudomonas fluorescens at 25%, 50% and 75% for 8 days. Besides, the higher germination per cent showed by biopriming treatments over control, the seeds subjected to biopriming for 4 days at different concentrations were on par with the best treatment. (Chitra *et al.*2019). Villarreal *et al*. (2019) reported that during the germination trials in useful tropical tree species *Albizia saman, Cedrela odorata* and *Swietenia macrophylla*, natural priming improved germination *whereas* hydropriming was most effective in increasing the germination of *Enterolobium cyclocarpum.*

MATERIALS AND METHODS

The study on "Biopriming techniques for better germination and seedling growth of sandal (*Santalum album*, L)''carried out at Department of Silviculture, College of Forestry, Kerala Agricultural University (KAU), Thrissur from May 2019 to June 2020. The materials used and methodology adopted for the study is depicted in this chapter.

3.1 MATERIALS

Sandal seeds for the present study was obtained from the Nachivayal Reserve Forest I and II of Marayur sandal Division located between 77^0 5' to 77^0 15' E longitude and 10^0 10' to 10^0 20' N latitude. The seeds were collected during October to November 2019.

3.1.1 Seed characters

The thousand seed weight was determined in ten replications using an electronic balance and expressed in grams. From the seedlot, 50 seeds were randomly selected to determine the individual seed weight, and diameter. The seed colour was determined visually.

3.2 METHODS

The sandal seeds were subjected to treatment with three biopriming agents (bio- inoculants) viz. *Pseudomonas fluorescens,* Plant Growth Promoting Rhizobacteria (PGPR II of KAU) and *Trichoderma viride.* PGPR II is a consortium of highly compatible rhizobacteria having broad spectrum of antagonistic properties. The suspension cultures of 10^8 CFU ml^{-1} were obtained from the Department of microbiology of College of Agriculture, Vellayani and College of Horticulture, Vellanikkara and of KAU. The sequence of steps from obtaining sandal seeds to subjecting them to different priming techniques are given in the following sections. The average weather parameters of the study area is given in Fig 1.

3.2.1 Seed Sampling

The sandal seed lot was thoroughly mixed to improve the homogeneity and the seeds were quarter divided four times. Seeds were randomly selected from the seedlot to conduct various priming treatments.

3.2.3 Seed Priming Methods

The seeds were surface sterilized using 0.1% Mercuric chloride for 5 minutes and thoroughly washed to remove the traces.

3.2.3.1 Biopriming

The priming agents selected for the present study was *Pseudomonas fluorescens*, Plant Growth Promoting Rhizobacteria (PGPR II of KAU) and *Trichoderma viride.* For the study 20 g of the powder formulations of the bioinoculants @ 10^8 CFU ml^{-1} is said to produce 100% concentration for 50 sandal seeds. Hence, the ratio of powder formulations to the number of seeds to be primed was taken in the ratio 2:5. The biopriming of seeds were carried out at four different concentrations of the powder formulations viz., 25, 50, 75 and 100% for 1, 2, 3, 4, 6 and 8 days. During the treatment distilled water was added to make up the volume of priming solution

sufficient to suspend the seeds within it. The glass bottle with seeds and powder formulation was covered with aluminum foil. The seeds were stirred at regular interval to prevent the powder formulation from hardening.

3.2.3.2Hydropriming

In order to hydroprime, the seeds were soaked in double distilled water for the same duration. Five hundred seeds weighing 70 to 90 g were hydroprimed with two times water. The seeds were transferred to a glass bottle and covered with aluminum foil. The brief description of the priming procedure is summarized in the Plate 1.

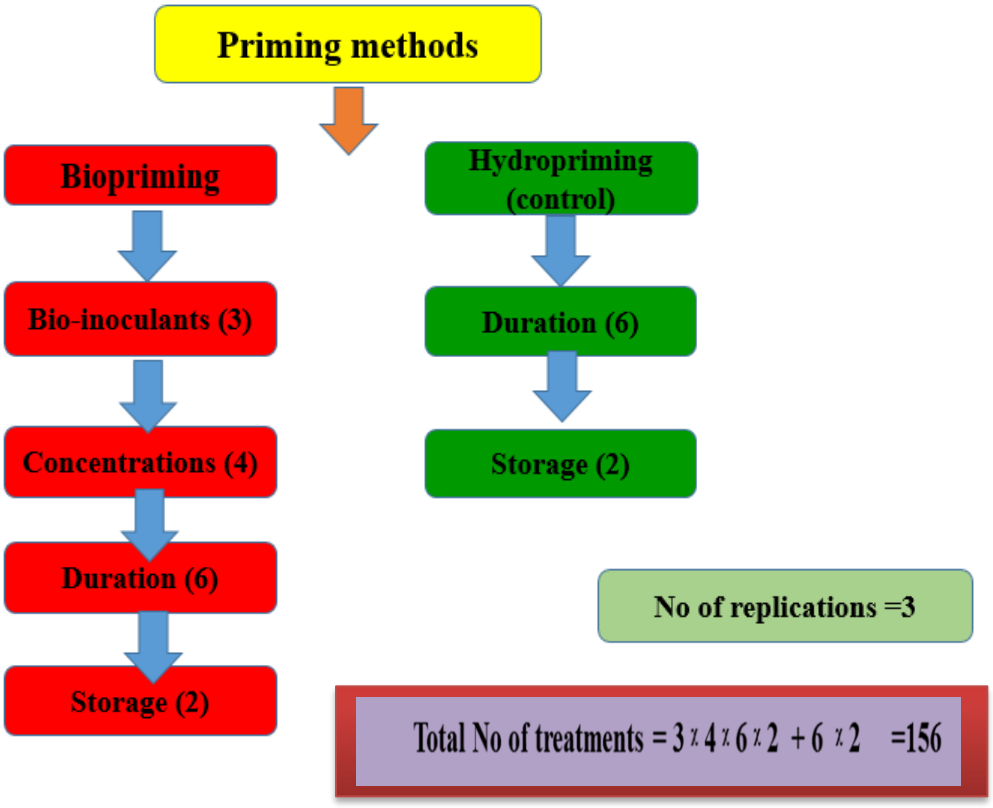

Plate 1. Flowchart of the priming experiment

3.2.4 Post Priming Process

The primed seeds were separated from the priming agents and thoroughly washed with distilled water thrice and dried with Whatman filter paper in shade at 25°C till the seeds achieved the moisture level prior to priming. The re-dried seeds were transferred to paper bags, kept in glass containers and stored at ambient condition for one day and one week.

3.2.6 Seed Pretreatment and sowing

The primed sandal seeds were pretreated with 500 mg l^{-1} w/v of GA_3 (Merck) overnight prior to sowing. Seed germination studies were conducted in the nursery and sand was used as the germination medium and the plastic trays of size 35x30x5 cm were used to fill the medium. The treated seeds were sown at a spacing of 5 cm x 5 cm with sowing depth of one cm. There were five rows and ten columns per treatment. There were 156

treatment combinations and each treatment had three replications of 50 seeds each. It was watered regularly and uniformly with a rose can until germination was completed.

3.2.8 Germination Study

Daily germination counts were recorded for a period of days from the start of germination by which germination was complete. Number of seedlings emerging on each day was recorded and the germination percentage was calculated. The germination value (GV) was calculated as suggested by Czabator (1962):

$$GV = MDG \times PV,$$

MDG = Final Mean Daily Germination, PV = Highest value of Mean Daily Germination.

The Mean Daily Germination is calculated as the cumulative percent of full seed germination at the end of germination test, divided by the number of days from sowing to the end of the test. Peak Value of germination actually denotes the speed of germination, which is the maximum mean daily germination, recorded at any time during the period of test.

3.2.9 Seedling growth and biomass production

In order to find the effect of priming on seedling parameters, 12 uniform seedlings having 4-6 leaves belonging to each priming treatments were be transplanted to polythene bags containing the medium soil, sand and cow dung in the ratio 3:1:1 for six months. The growth attributes, biomass production observations were made at 30 and 180 days after transplanting (DAT).

3.2.9.1 Seedling height

The height of the seedlings was measured from the ground level to the tip of the main shoot using a meter scale and the mean height was recorded (cm).

3.2.9.2 Collar diameter

The collar diameter of seedlings from each treatment was measured using a Vernier caliper and was expressed as the mean diameter in mm.

3.2.9.3 Leaf number and Leaf area

Leaves from each seedling were detached to record the total leaf area. The total leaf area of seedlings was recorded using Systronics Leaf area Meter 21 I and the average leaf area (cm^2); the number of leaves were counted.

3.2.9.4 Root length and Number of lateral Roots

The root length of was measured using a meter scale and was expressed as cm. The number of roots emerging from the taproot was counted for each seedling and recorded.

3.2.9.5 Seedling Fresh and dry weight

After the destructive sampling of the seedlings the fresh weight of leaf, stem and root were separately recorded and total fresh weight taken as the cumulative total of the fresh leaf, stem and root and expressed in grams. In order to determine the dry weight of the each biomass component, the samples were dried to constant

weight in a hot air oven maintained at 70^0C for 48 h to estimate the dry weight. The dry weight was obtained from the moisture corrections.

3.3 Growth analysis indices

3.3.1 Vigour Indices

The vigour index of the seedlings was estimated as the suggested by Abul-Baki and Anderson, 1973:

$$\mathbf{VI} = \mathbf{GP} \times (\mathbf{SL} + \mathbf{RL})$$

Where, VI = Vigour index, GP = Germination percentage, SL = Shoot height and RL = Root length.

3.3.2 Root: Shoot Ratio

The root: shoot ratio of the seedlings were worked out using the following formula (Hunt, 1990):

$$\text{Root: ShootRatio} = \frac{\text{Rootdryweight (g)}}{\text{Shootdryweight (g)}}$$

3.3.3 Leaf Area Ratio

According to Radford (1967) Leaf Area Ratio is an expression of the amount of leaf area formed per unit of biomass. It is expressed as $cm^2\ g^{-1}$ of plant dry weight.

$$\text{Leaf Area Ratio} = \frac{\text{Leaf Area per Plant}}{\text{Plant Dry Weight}}$$

3.3.4 Leaf Weight Ratio

Leaf weight ratio is an expression of the leaf dry weight to the whole plant dry weight. It was suggested by Kvet *et al*., (1971).

$$\text{Leaf Weight Ratio} = \frac{\text{Leaf Dry Weight}}{\text{Plant Dry Weight}}$$

3.4 Electrical conductivity of seed leachates

The electrical conductivity of normal and undamaged seeds belonging to different priming treatments was determined. The leachates of seeds immediately after priming were subjected to EC measurement in conductivity meter (CDC 40101). Five ml of the leachate was transferred to a 25 ml standard flask and to make up the volume by adding distilled water. The EC was directly obtained from conductivity meter and was expressed as dS cm^{-1}.

3.5 Biochemical Analysis

The methodology for determination of biochemical constituents like total carbohydrate, protein and crude fat content is given in the following sections.

3.5.1 Total carbohydrate

The total carbohydrate of the control and primed seeds was estimated by Antrone Reagent (Yemm and Wills (1954)) and is expressed in mg g^{-1}.

Weighed 1g of sample and crushed in a flask. Hydrolyzed the tissue by keeping it in 50 ml of 2.5N HCl for three hours at 100℃ in a water bath. Neutralized the excess HCl with sodium carbonate .Volume was made up to 100ml. Take 7 test tube. The standard curve was prepared using standard. Added 4 ml anthrone reagent (ice cold) into all test tubes. Mixed and kept for 10 minutes in boiling water bath. The test tube was cooled and read at wavelength 630 nm. The amount of total carbohydrate was calculated using the following formula.

$$\mathbf{Totalcarbohydrate} = \frac{\mathbf{Xmg \times V \times 1000}}{\mathbf{Amount\ of\ aliquot\ pipetted \times W}}$$

Where, X= the amount of carbohydrate obtained from the standard curve

V= Volume of the sample taken

W= Weight of the seed sample taken

3.5.2 Total Protein

The total protein was estimated by the Lowry *et al* method (1951) and is expressed in mg g^{-1}. Ground 0.5 g of the sample with distilled water/ buffer in mortar and pestle. Centrifuged and take supernatant for protein estimation. Five standards are prepared (0.2, 0.4, 0.6, 0.8 and 1). Blank as B. Test sample was taken in another test tube. Added distilled water uniformly in all tubes to make volume up to 1 ml. Added 5 g of Solution C and 0.5 g FCR to all tubes .The intensity of blue colour developed was read at 660 nm after 30 minutes in a spectrophotometer. The total protein content in the sample was calculated using the following formula.

$$\mathbf{TotalProtein} = \frac{\mathbf{X\ mg \times V \times 1000}}{\mathbf{Amount\ of\ aliquot\ pipetted \times W}}$$

Where, X= the amount of protein obtained from the standard curve

V= Volume of the sample taken

W= Weight of the seed sample taken

3.5.3 Crude Fat

The crude fat content was estimated by Soxhlet method of extraction (Kennedy, 1949) and is expressed in %.

Procedure

Five gram of seed samples were weighed and ground to a homogenous mixture using pestle and mortar. In order to facilitate fast and optimum extraction of the crude fat, the ground sample was packed between 2 cm thick cotton layers when transferred to the thimble. The pre-dried extraction flask was connected beneath the thimble and was placed in the mantle. Further, to reduce the extraction time, 150 ml of the solvent was slowly poured in to the ground sample in thimble from top, until the complete solvent with extract reached the extraction flask. The thimble was then connected to the condenser. The temperature was adjusted to 70^0 C and

the extraction was carried out for 2.5 h by the time which the colour of solvent became transparent. Once the extraction was completed, the thimble and solvent flask were detached from the apparatus and the content of the flask was emptied to a dry pre – weighed beaker. The excess solvent present in the extract was removed by keeping the beaker on a hot water bath until a constant weight was obtained. The beaker was then cooled and the final weight was recorded. The amount of crude fat was expressed in percentage. The crude fat in the given sample was calculated using the following formula:

$$\textbf{Crude fat}\ (\%) = \frac{\mathbf{W_2 - W_1}}{\textbf{Weight of the sample}} \times \mathbf{100}$$

Where, W_2 = Final weight of beaker with crude fat

W_1 = Initial weight of the beaker

3.7 Statistical Analysis

The design of the experiment was factorial CRD. The data were analysed for individual priming treatments in two-way analysis of variance with concentration of the bioinoculant and duration of the treatment as the two factors. The statistical analysis was conducted using the IBM SPSS Statistics 21 software and Agricolae under R environment (Mendiburu, 2015). Hierarchical cluster analysis, an algorithm that groups similar objects into clusters, was carried out for the 78 treatments (including control) based on the Euclidean Distance. The average weather parameters during the study period is given in Fig 1.

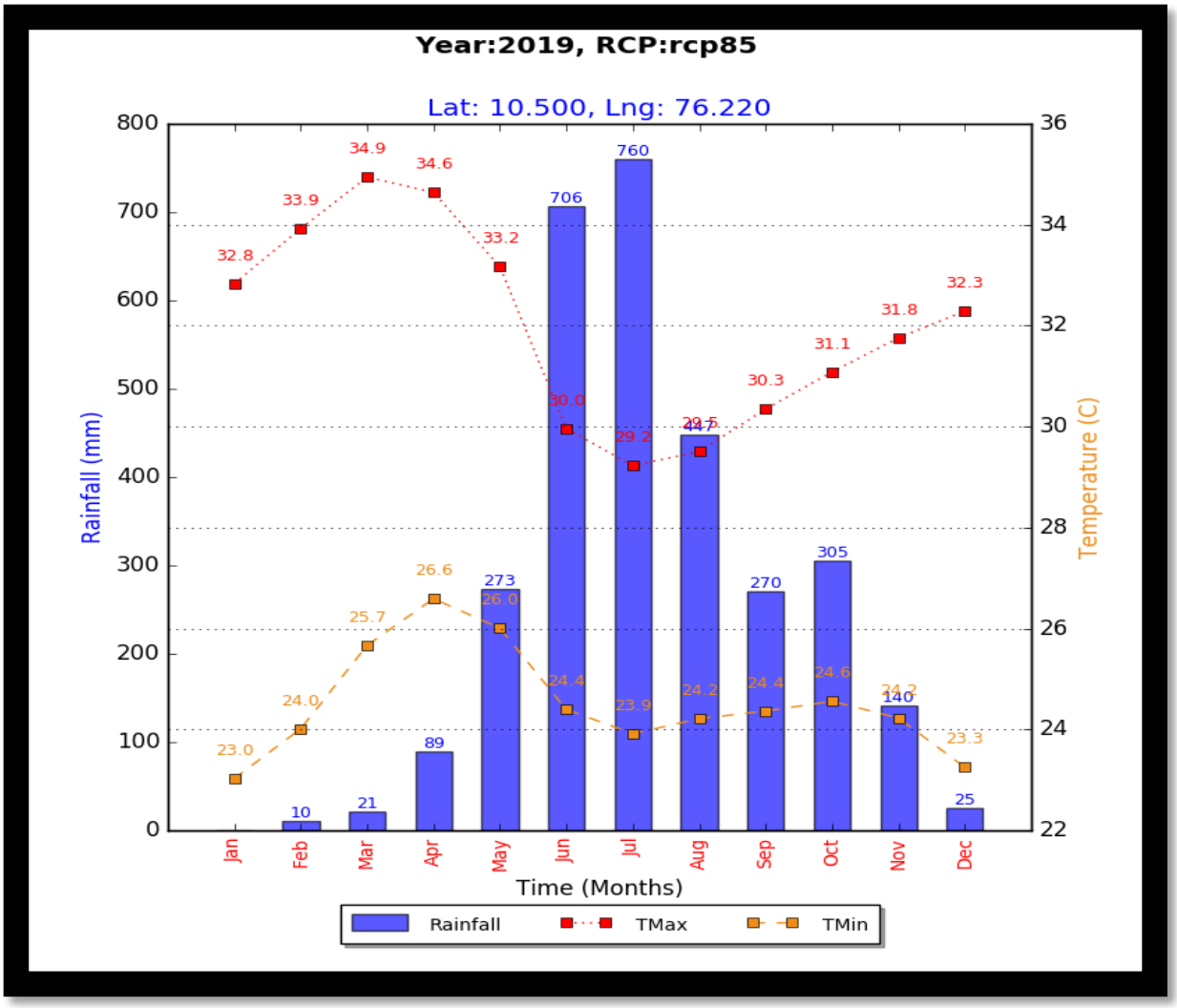

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Fig 1. The average weather parameters during the study period.

RESULTS

The results of the study entitled "Biopriming techniques for better germination and seedling growth of sandal (*Santalum album*, L)'', are presented in the following sections. Effect of biopriming and hydropriming on

germination and seedling performance measured in terms of seedling growth, biomass production and growth analysis indices of sandal are discussed in detail. The primed seeds were sown after storing for one day and one week.

4.1 Seed characteristics of sandal

Examination of physical characteristics indicated that the sandal seeds were with a brown hard seed coat and the average size of the seeds ranged from 0.7-0.9 cm. The seed diameter ranged from 0.5 to 1.0 cm. Seed moisture content was in the range of 10-15%**.**The individual seed weight ranged from 0.15 to 0.27 g whereas the seed kernel weighed an average of 0.01 to 0.02 g and the 1000 seeds weighed 250 g.

4.2 Germination attributes of sandal seeds

The effects of different durations and concentrations of various biopriming agents on the germination attributes of sandal seeds are presented in the following sections.

4.2.1 Biopriming with *Pseudomonas fluorescens*

The variation in the germination attributes of sandal seeds stored for one day after the biopriming treatment with *P. fluorescens* are presented in Table 1. The highest germination was obtained for the seeds subjected to biopriming at 25% for 3 days (35%) and the lowest was obtained for biopriming at 50% for 2 days (0%) under the storage duration of one day. The MDG, PV and GV was highest for biopriming at 25% for 4 days (4.00, 3.06 and 12.24, respectively) and the minimum for biopriming at 75% for 1 day for one day storage (0.04, 0.09, and 0.0036, respectively). The interaction between concentration and duration of the bioinoculant was significant ($F=54.159$, $p < 0.01$) at 1% level in germination percentage. Table 2 depicts the germination attributes of primed seeds stored for one week, the highest germination was obtained for the seeds that were subjected to biopriming at 100% for 6 days (81%) and the lowest was obtained for the seeds subjected to biopriming at 25 % for 3 days (8%). The MDG, PV and GV was highest in biopriming at 75% concentration for 8days (6.42, 6.42 and 41.23, respectively) and the minimum was at 50 % for 1day (0.74, 0.82, and 0.61, respectively). The interaction effect between the concentration and duration were significant in germination percentage ($F=3.718$, $p < 0.01$) at 1% level. The germination of primed seeds subjected to post priming storage was almost double compared to those stored for one day storage.

Table 1 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the germination attributes of sandal seeds subjected to post priming storage of one day

Pseudomonas fluorescens		Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
Concentration (%)	Duration (days)						
25	1	22	49	33.93^{ic}	2.04	2.08	4.25
	2	31	39	31.95^{ic}	1.00	1.00	1.00
	3	23	27	34.64^{ic}	1.35	1.48	2.01
	4	17	28	14.68^{fgh}	4.00	3.06	12.24
	6	14	28	1.22^{abc}	0.33	0.17	0.06
	8	21	28	10.70^{ef}	1.86	1.18	2.19
	1	19	31	10.70^{ef}	0.25	0.10	0.03
	2	-	-	-	-	-	-

50	3	15	31	17.32^{hi}	0.50	0.30	0.15
	4	20	40	15.32^{gh}	1.44	0.76	1.10
	6	24	28	24.00^{i}	2.60	1.08	2.82
	8	25	28	6.618^{de}	1.22	0.73	0.90
75	1	20	34	3.84^{cd}	0.04	0.09	0.0036
	2	25	34	6.62^{de}	3.69	3.00	11.08
	3	20	30	6.62^{de}	0.38	0.69	0.26
	4	20	27	7.29^{de}	3.27	2.40	7.85
	6	17	24	9.24^{efg}	2.91	1.57	4.57
	8	21	26	1.76^{abc}	0.85	1.00	0.85
100	1	18	28	1.22^{abc}	0.43	0.21	0.09
	2	20	50	14.68^{fgh}	1.75	0.90	1.57
	3	15	22	0.54^{ab}	0.50	0.29	0.14
	4	21	30	2.61^{bc}	1.43	0.74	1.06
	6	19	44	8.67^{ef}	0.84	1.04	0.87
	8	13	28	19.34^{hi}	1.93	2.07	4.00
Values within the same column with similar superscripts are homogenous.							

Table 2 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the germination attributes of sandal seeds subjected to post priming storage of one week.

Pseudomonas fluorescens		Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
Concentration (%)	Duration (days)						
25	1	23	40	15.32^{b}	1.35	1.15	1.56
	2	15	34	9.30^{a}	0.83	1.16	0.96
	3	15	21	8.00^{a}	1.64	2.00	3.28
	4	15	56	64.29^{ie}	2.46	3.61	8.89
	6	15	50	19.34^{c}	2.78	3.68	10.24
	8	15	41	23.30^{def}	3.00	2.09	6.26
50	1	15	48	46.61^{i}	0.74	0.82	0.61
	2	17	34	48.00^{i}	1.35	1.71	2.30
	3	16	41	27.30^{g}	0.94	1.27	1.19
	4	16	49	20.62^{cd}	2.07	2.07	4.27
	6	15	57	22.04^{cde}	4.88	4.74	23.16
	8	16	55	37.31^{i}	4.11	2.85	11.70
75	1	15	56	67.39^{i}	2.00	1.14	2.29
	2	15	30	20.62^{cd}	2.12	2.92	6.19
	3	16	34	32.64^{h}	0.79	1.16	0.91
	4	23	41	24.00^{ef}	2.72	2.88	7.85
	6	19	56	68.72^{i}	3.76	3.76	14.17
	8	18	35	55.40^{i}	6.42	6.42	41.23
100	1	17	34	42.69^{i}	2.37	3.46	8.20
	2	15	28	25.32^{fg}	4.24	4.24	17.94
	3	15	23	15.97^{b}	1.44	2.04	2.92
	4	17	26	24.70^{efg}	2.00	1.76	3.51
	6	19	38	81.26^{i}	2.92	2.71	7.93
	8	19	48	46.61^{i}	2.41	2.92	7.04
Values within the same column with similar superscripts are homogenous.							

4.2.2 Biopriming with *Trichoderma viride*

Table 3 depicts the germination attributes of sandal seeds sown after storing for one day after biopriming with *T. viride.* For one day storage, the highest germination was obtained for the seeds subjected to biopriming at 100 % for 1 day (73%) and the lowest value was obtained for those at 25% for 8days (3%). The MDG, PV and GV were highest for biopriming at 25% for 4 days (4.91, 3.72 and 18.28, respectively) and the minimum values for biopriming at 50 % for 2 days. (0.4, 0.27 and 0.11 respectively Analysis of variance revealed significant difference in germination percentages of sandal seeds due to the interaction of concentration and duration ($F=93.620$, $p < 0.01$) at 1% level. Regarding the one week storage (Table 4), the highest germination was obtained on biopriming at 100% for 3 days (83%) and the lowest was obtained for the seeds subjected to biopriming at 100 % for 6 days (1%).The MDG, PV and GV were highest for biopriming at 50% for 3 days(5.736, 6.411 and 36.78, respectively) and the minimum for biopriming at 100 % for 8 days (0.371, 0.49 and 0.18221, respectively).The difference in germination percentage was significant ($F=698.550$, $p < 0.01$) at 1% level due to interaction effect of concentration and duration of bioinoculant.

Table 3 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the germination attributes of sandal seeds subjected to post priming storage of one day

Trichoderma viride		Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
Concentration (%)	Duration (days)						
25	1	21	32	34.60^{i}	4.82	3.31	15.96
	2	16	34	16.64^{gh}	2.50	1.25	3.13
	3	24	28	6.02^{b}	1.04	1.16	1.20
	4	19	28	12.61^{ef}	4.91	3.72	18.28
	6	19	24	9.96^{cde}	2.43	1.21	2.95
	8	21	30	2.61^{a}	2.60	2.29	5.96
50	1	24	67	24^{i}	1.19	1.47	1.75
	2	17	35	25.32^{i}	0.40	0.27	0.11
	3	21	50	19.34^{h}	1.89	1.17	2.21
	4	21	29	11.32^{de}	1.75	1.00	1.75
	6	21	32	10.63^{cde}	1.35	1.12	1.52
	8	19	66	9.30^{cd}	1.39	1.35	1.88
75	1	19	29	35.97^{i}	1.80	0.64	1.16
	2	20	70	9.30^{cd}	3.27	2.48	8.13
	3	16	35	11.32^{de}	1.45	1.00	1.45
	4	24	32	8.00^{bc}	0.89	0.97	0.87
	6	21	28	11.32^{de}	2.97	3.10	9.21
	8	16	41	15.32^{fg}	2.47	2.11	5.22
100	1	18	71	73.30^{i}	2.11	1.36	2.87
	2	17	37	19.34^{h}	2.11	2.17	4.58
	3	19	34	26.04^{i}	1.27	1.00	1.27
	4	19	37	16.64^{gh}	1.50	0.75	1.13
	6	20	35	24.70^{i}	1.53	1.57	2.39
	8	23	39	32.64^{i}	2.88	2.51	7.24
Values within the same column with similar superscripts are homogenous.							

Table 4 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the germination attributes of sandal seeds subjected to post priming storage of one week.

Trichoderma viride		Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
Concentration (%)	Duration (days)						
25	1	17	33	46.61^{i}	4.38	4.24	18.56
	2	16	34	55.40^{i}	1.04	1.17	1.21
	3	19	24	6.02^{b}	2.03	2.54	5.17
	4	16	42	18.62^{d}	3.13	3.13	9.82
	6	21	48	18.62^{d}	1.54	1.80	2.78
	8	16	33	29.36^{g}	5.39	6.20	33.43
50	1	15	34	42.69^{i}	4.61	4.88	22.51
	2	20	48	35.97^{hi}	2.59	2.67	6.90
	3	18	48	40.60^{i}	5.74	6.41	36.78
	4	15	34	72.61^{i}	1.08	0.79	0.85
	6	16	56	36.70^{i}	3.14	2.93	9.22
	8	21	52	10.02^{c}	1.80	2.62	4.71
75	1	15	30	31.38^{gh}	1.80	0.75	1.35
	2	21	33	8.67^{c}	3.37	3.76	12.68
	3	15	25	15.97^{d}	1.38	1.96	2.70
	4	15	29	23.30^{e}	2.40	1.92	4.61
	6	17	41	24.70^{ef}	1.84	2.50	4.61
	8	16	30	29.36^{g}	1.88	2.68	5.02
100	1	18	56	46.61^{i}	1.08	1.33	1.44
	2	15	35	28.05^{fg}	1.93	2.25	4.34
	3	17	40	82.72^{i}	0.48	0.58	0.28
	4	15	55	48.00^{i}	2.50	2.41	6.03
	6	16	56	1.22^{a}	2.10	2.40	5.04
	8	18	53	8.67^{c}	0.37	0.49	0.18
Values within the same column with similar superscripts are homogenous.							

4.2.3. Biopriming with Plant growth promoting Rhizobacteria (PGPR II)

The trends in the germination attributes of sandal seeds stored for one day after the biopriming treatment with PGPR II are presented in Table 5. For one day storage, the highest germination was obtained for the seeds subjected to biopriming at 75 % for 6 days (29%) and the lowest value was obtained in biopriming at 50% for 3 days (1%).The MDG, PV and GV were highest for biopriming for 25% for 2 day (4.55 ,3.41 and 15.56 ,respectively) and the minimum for biopriming at 50 % for 1 day (1, 0.25 and 0.25, respectively).In the context of one week storage (Table 6) , the highest germination was obtained for the seeds, subjected to biopriming at 50% for 3 days (77%) and no germination was obtained for the seeds subjected to biopriming at 100% for 3 days as well as in 25 % for 1 day. For one week storage also, the MDG, PV and GV were highest for biopriming at 25% for 3 day (6.76, 6.57and 44.45, respectively) and the minimum for biopriming at 25% for 1 day and 100% for 3 days. The interaction between concentration and duration was significant in germination percentage at one day ($F=65.667$, $p < 0.01$) and one week ($F=1909.205$, $p < 0.01$) storage.

Table 5 Effect of biopriming with different concentrations of PGPR II at various durations on the germination attributes of sandal seeds subjected to post priming storage of one day

PGPR 2		Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
Concentration (%)	Duration (days)						
25	1	21	35	21.28^{i}	1.52	1.83	2.79
	2	21	24	1.76^{a}	4.56	3.42	15.56
	3	20	28	8.67^{bc}	2.00	0.19	0.38
	4	21	28	8.00^{b}	2.27	2.27	5.14
	6	19	27	27.30^{i}	2.32	2.51	5.82
	8	22	26	3.28^{a}	1.35	1.50	2.03
50	1	21	35	13.28^{defg}	1.00	0.25	0.25
	2	19	28	15.32^{efgh}	2.50	0.38	0.96
	3	21	21	1.22^{a}	1.86	1.86	3.45
	4	14	28	17.32^{fghi}	2.13	1.21	2.58
	6	20	25	9.30^{bcd}	2.43	0.72	1.76
	8	20	28	8.00^{b}	2.00	1.08	2.15
75	1	15	30	22.62^{i}	0.89	1.00	0.89
	2	19	28	11.32^{bcde}	1.43	1.00	1.43
	3	21	38	17.32^{fghi}	2.80	1.17	3.27
	4	18	26	10.63^{bcde}	2.36	1.63	3.84
	6	18	35	29.36^{i}	2.22	1.57	3.49
	8	23	47	11.32^{bcde}	1.58	1.19	1.88
100	1	19	28	14.68^{efg}	1.50	0.86	1.29
	2	18	28	20.62^{hi}	2.56	1.64	4.20
	3	16	36	18.01^{ghi}	1.50	0.86	1.29
	4	19	26	9.30^{bcd}	2.00	1.23	2.46
	6	13	32	12.61^{cdef}	3.44	2.21	7.63
	8	21	28	8.00^{b}	1.50	0.86	1.29
Values within the same column with similar superscripts are homogenous.							

Table 6 Effect of biopriming with different concentrations of PGPR II at various durations on the germination attributes of sandal seeds subjected to post priming storage of one week.

PGPR 2		Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
Concentration (%)	Duration (days)						
25	1	-	-	-	-	-	-
	2	18	42	18.62^{hi}	2.05	2.32	4.76
	3	19	42	29.36^{i}	6.76	6.57	44.45
	4	23	34	6.02^{c}	2.00	0.52	1.04
	6	16	37	28.70^{i}	4.20	2.00	8.40
	8	32	35	4.02^{b}	0.82	1.00	0.82
50	1	15	41	20.62^{i}	1.17	1.33	1.56
	2	15	25	18.01^{hi}	2.00	0.34	0.69
	3	18	35	76.62^{i}	2.26	2.46	5.56
	4	16	35	28.70^{i}	4.67	4.12	19.22
	6	16	34	11.32^{e}	1.78	1.33	2.37

	8	18	46	15.32^{fg}	0.75	0.52	0.39
75	1	20	23	4.02^{b}	1.91	2.10	4.01
	2	19	34	46.61^{i}	1.19	1.51	1.80
	3	18	25	6.02^{c}	0.94	1.00	0.94
	4	15	48	20.62^{i}	1.29	0.72	0.93
	6	16	21	13.98^{f}	0.41	0.53	0.22
	8	15	24	10.63^{e}	0.53	0.72	0.38
100	1	16	45	8.00^{d}	0.82	0.53	0.43
	2	17	48	42.69^{i}	2.70	2.16	5.83
	3	-	-	-	-	-	-
	4	15	23	4.02^{b}	0.94	1.29	1.21
	6	15	47	11.32^{b}	2.06	2.67	5.51
	8	15	34	17.32^{gh}	1.37	1.53	2.09
Values within the same column with similar superscripts are homogenous.							

4.2.4 Hydro priming

The results of germination attributes of sandal seeds subjected to hydropriming and stored for one day are presented in Table 7. The highest germination was obtained for the seeds subjected to hydropriming for 2 days (30%) and the lowest was obtained on hydropriming for 1 days (6%) for one day storage. The MDG, PV and GV were highest for hydropriming for 6 days (3.11, 2 and 6.22, respectively) and was the minimum on hydropriming for 4 days (2, 0.52 and 1.04, respectively). For one week storage (Table 8), the highest germination was obtained for the seeds that were subjected to hydropriming for 8 days (56%) and the lowest was in hydropriming for 4 days (11%). The MDG, PV and GV were highest for hydropriming for 6 days (3.38, 2.84, and 9.61 respectively) and the minimum on hydropriming for 2 days (0.78, 0.878 and 0.6871 respectively). The germination of sandal seeds were improved by storing the seeds primed for one week. Statistical analysis revealed the significant difference in germination percentage of sandal seeds due to the duration at one day ($F= 295.826$, $p < 0.01$) and one week ($F= 397.583$, $p < 0.01$) storage.

Table 7 Effect of hydropriming at various durations on the germination attributes of sandal seeds subjected to post priming storage of one day

Hydropriming (days)	Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
1	24	27	6.40^{a}	2.67	0.59	1.58
2	21	33	30.14^{c}	1.58	1.15	1.82
3	16	18	26.56^{bc}	3.00	0.67	2.00
4	21	24	13.06^{ab}	2.00	0.52	1.04
6	19	28	15.65^{abc}	3.11	2.00	6.22
8	17	34	6.45^{a}	2.53	2.53	6.40
Values within the same column with similar superscripts are homogenous.						

Table 8 Effect of hydropriming at various durations on the germination attributes of sandal seeds subjected to post priming storage of one week.

Hydropriming (days)	Imbibition period	Germination period	Germination per cent	Mean Daily Germination	Peak Value	Germination Value
1	18	34	27.30^{b}	2.56	2.41	6.18
2	18	41	12.03^{a}	0.78	0.88	0.69

3	17	57	27.94[b]	1.05	1.47	1.55
4	17	26	10.63[a]	1.78	1.23	2.19
6	18	31	29.30[b]	3.38	2.84	9.61
8	15	41	56.00[c]	3.23	4.10	13.24
Values within the same column with similar superscripts are homogenous.						

4.3 Electrical conductivity of seed leachates

The changes in electrical conductivity of seed leachates of primed seeds at different duration and concentration of the bioinoculants and hydropriming are given in the following section.

4.3.1. Effect of biopriming with *Pseudomonas fluorescens* on the electrical conductivity of seeds leachates

The variation in the electrical conductivity of the seed leachates subjected to biopriming with *Pseudomonas fluorescens* is given in Fig 3. The highest EC was observed for seeds subjected to biopriming treatment for 75% for 4 days (1.159 dS cm^{-1}) and the lowest was for the seeds subjected to biopriming for 25% for 6 days (0.325 dS cm^{-1}). The difference in electrical conductivity of the seed leachates varied due to the interaction effect of concentration and duration ($F=365.011$, $p < 0.01$).

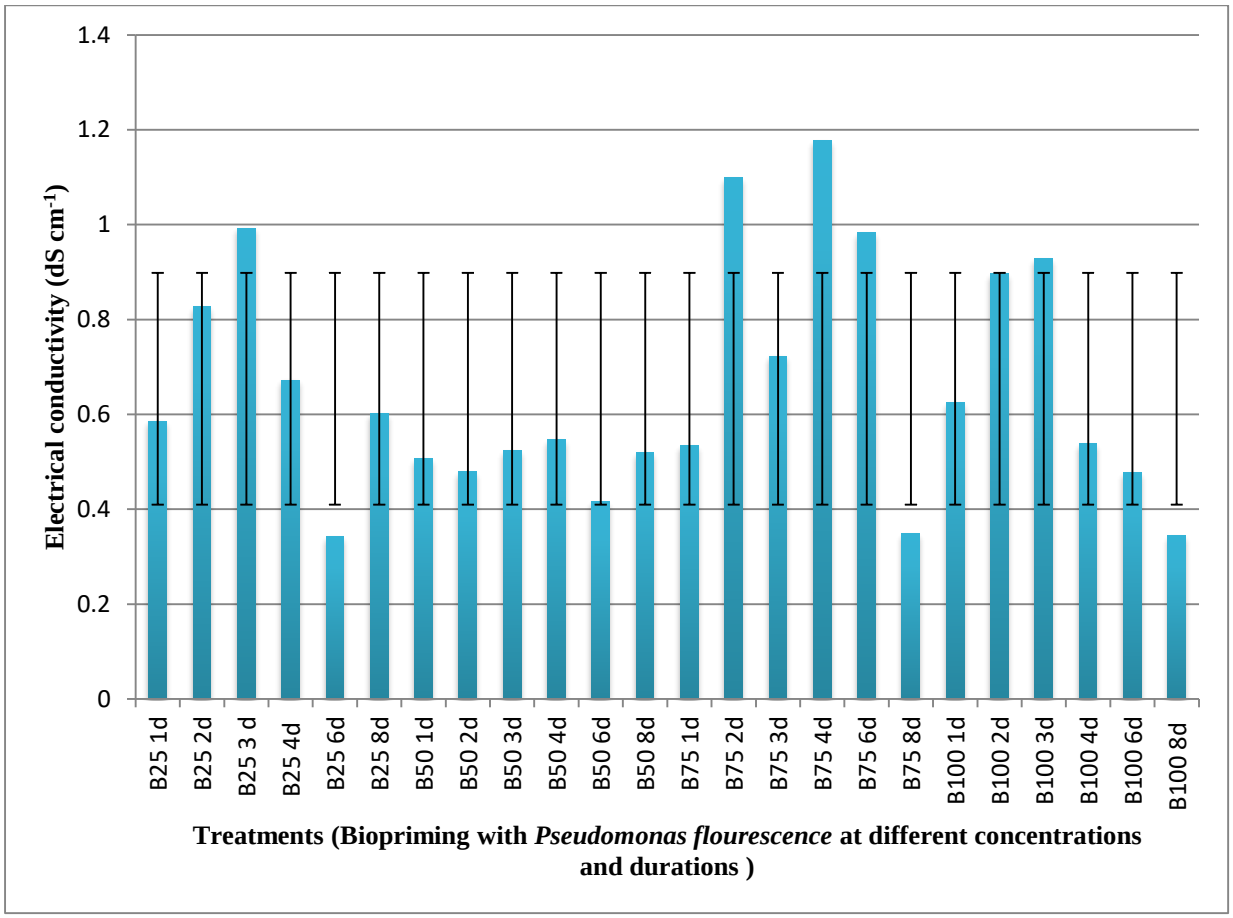

Fig 3 Effect of biopriming with *Pseudomonas fluorescens* on the electrical conductivity of sandal seed leachates

4.3.2 Effect of bio priming with *Trichoderma viride* on the electrical conductivity of seeds leachates

The variation in the electrical conductivity (EC) of the seed leachates subjected to biopriming with *Trichoderma viride* is given in Fig 4 .The highest EC was observed for seeds subjected to biopriming at 75% for 6 days (1.302 $dScm^{-1}$) and the lowest was in biopriming for 75% for 1 day (0.217 $dScm^{-1}$) .The interaction effect of priming concentration and duration was ($F=342.883$, $p < 0.01$) significant in electrical conductivity.

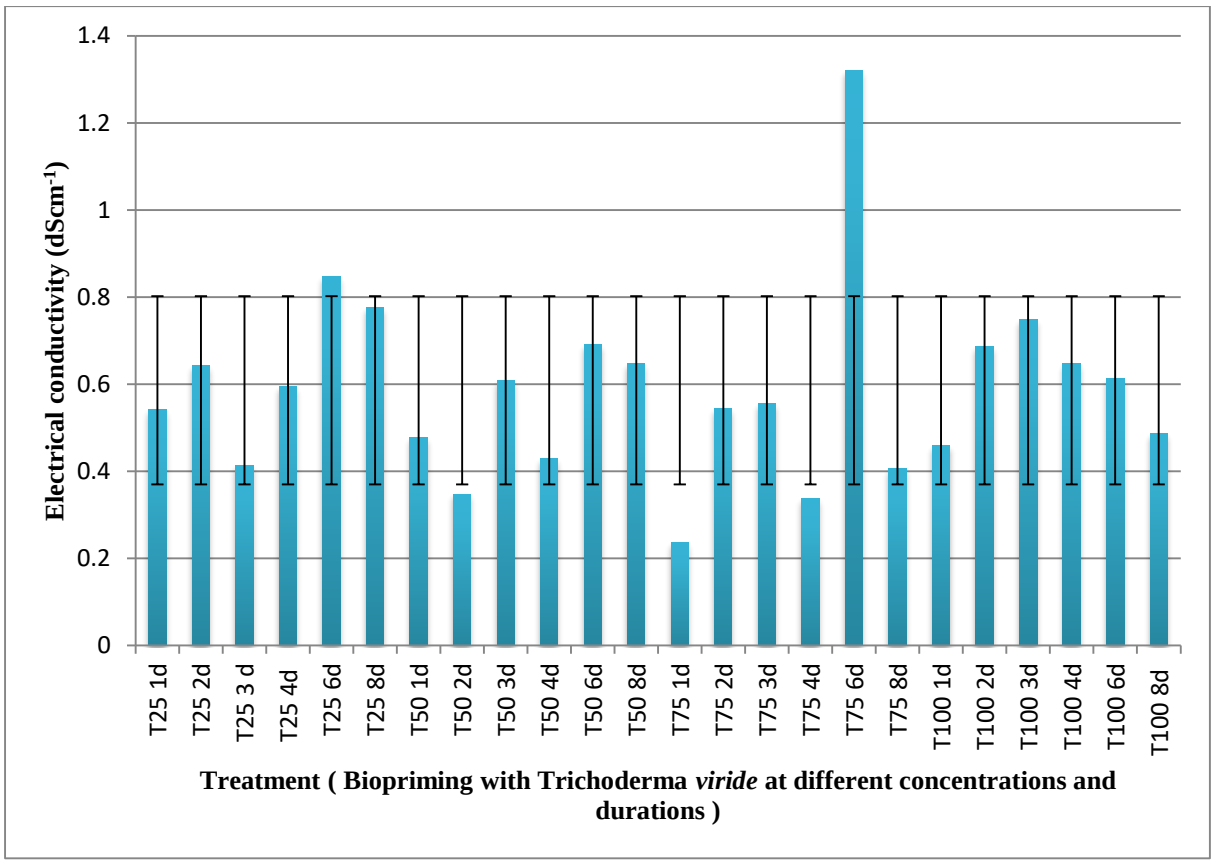

Fig 4 Effect of biopriming with *Trichoderma viride* on the electrical conductivity of sandal seed leachates

4.3.3. Effect of biopriming with PGPR II on the electrical conductivity of seeds leachates

The electrical conductivity of the seed leachates subjected to biopriming with PGPR II is given in Fig 5 .The highest EC was observed in seeds subjected to biopriming treatment at 25% for 2 days (0.962 dS cm^{-1}) and the lowest was for the seeds subjected to biopriming at 100% for 1 day (0.247 dS cm^{-1}). The electrical conductivity of the sandal seeds differed significantly due to interaction effect of concentration and duration ($F= 116.519$, $p < 0.01$).

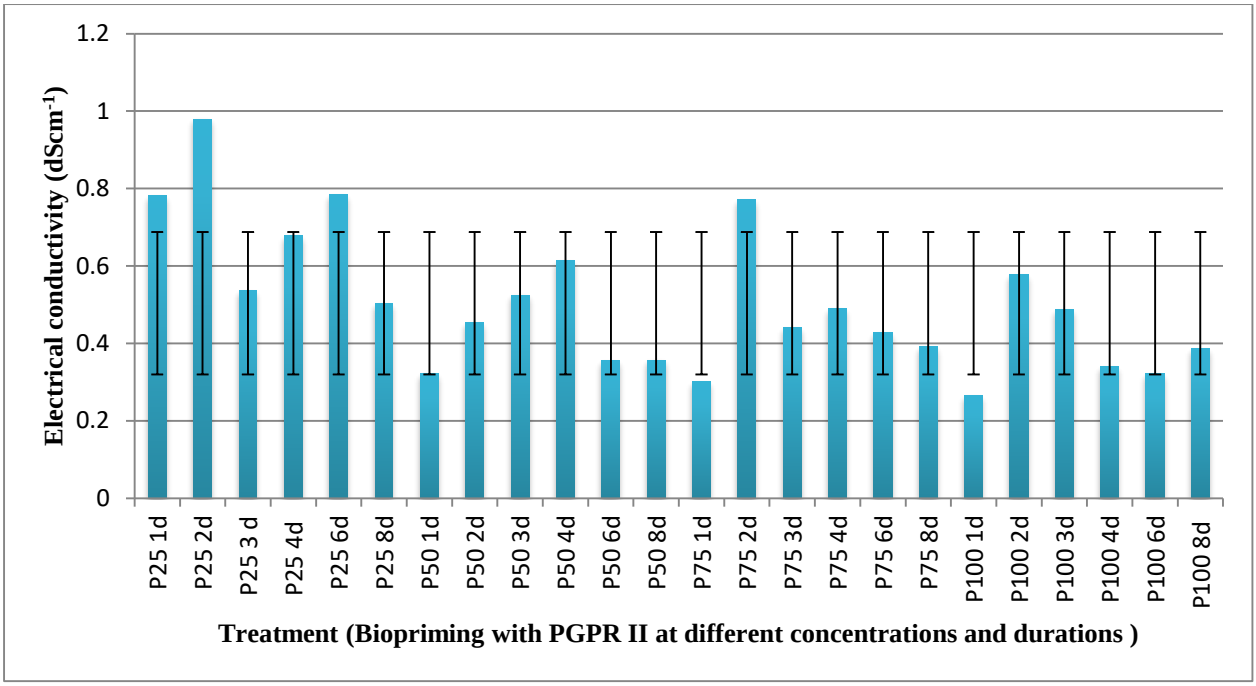

Fig 5 Effect of biopriming with PGPR II on the electrical conductivity of sandal seed leachates

4.3.4 Effect of hydropriming on the electrical conductivity of seeds leachates

The variation in the EC of the seed leachates subjected to hydropriming for different durations is given in Fig 6. The highest EC was observed for seeds hydroprimed for 2 days (1.450 dS cm^{-1}) and the lowest was for the seeds hydroprimed for 6 days (0.153 dS cm^{-1}) .The difference in EC due to the duration of hydro priming ($F= 2234.709$, $p < 0.01$) was significant.

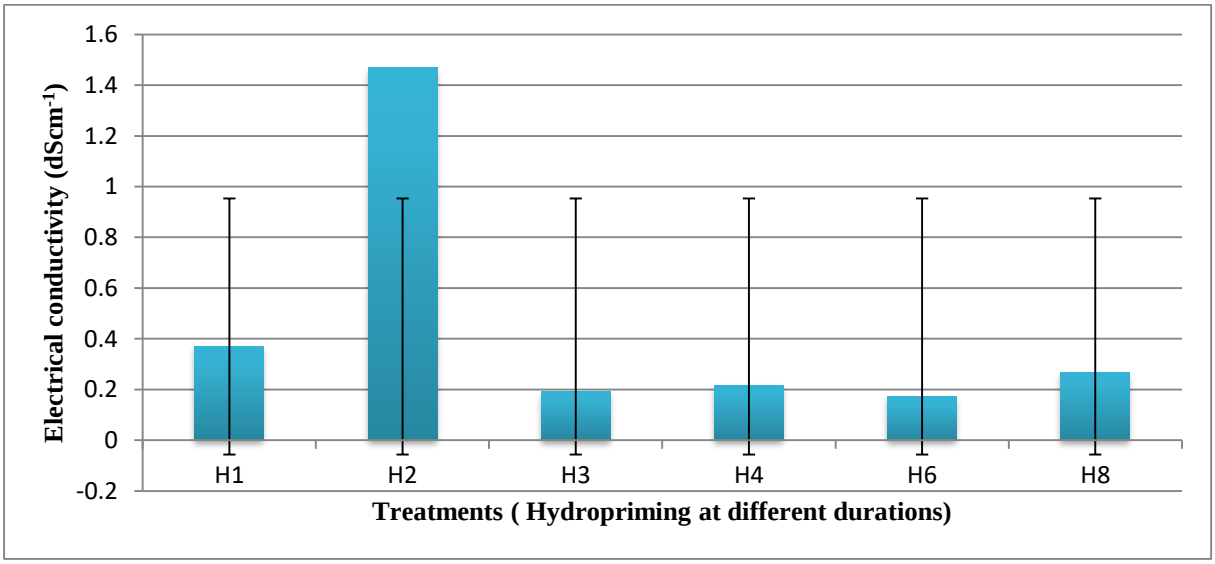

Fig 6 Effect of hydropriming on the electrical conductivity of sandal seed leachates

4.4. Variation in biochemical composition of the sandal seeds due to priming

The effect of the concentrations and durations of the different priming agents on the seed reserve materials *viz*, total carbohydrate, protein and crude fat are given below.

4.4.1. Biopriming with *Pseudomonas fluorescens*

The variation in total carbohydrate, protein and fat content of seeds bioprimed with *P. fluorescens* are given in Fig 7-9. The highest amount of carbohydrate was observed in seeds subjected to biopriming at 100% for 3 days (0.3337 mg g-1) and the lowest was at 50% for 6 days (0.0879 mg g-1). The highest protein content was observed in seeds bioprimed at 25 % for 6 days (0.062 mg g^{-1}) and the lowest value was at 50% for 1day (0.016 mg g-1). Meanwhile, the highest fat content was observed for seeds primed at 100% for 3 days (73.2%) and the lowest was at 100% for 2 days (44.6%).

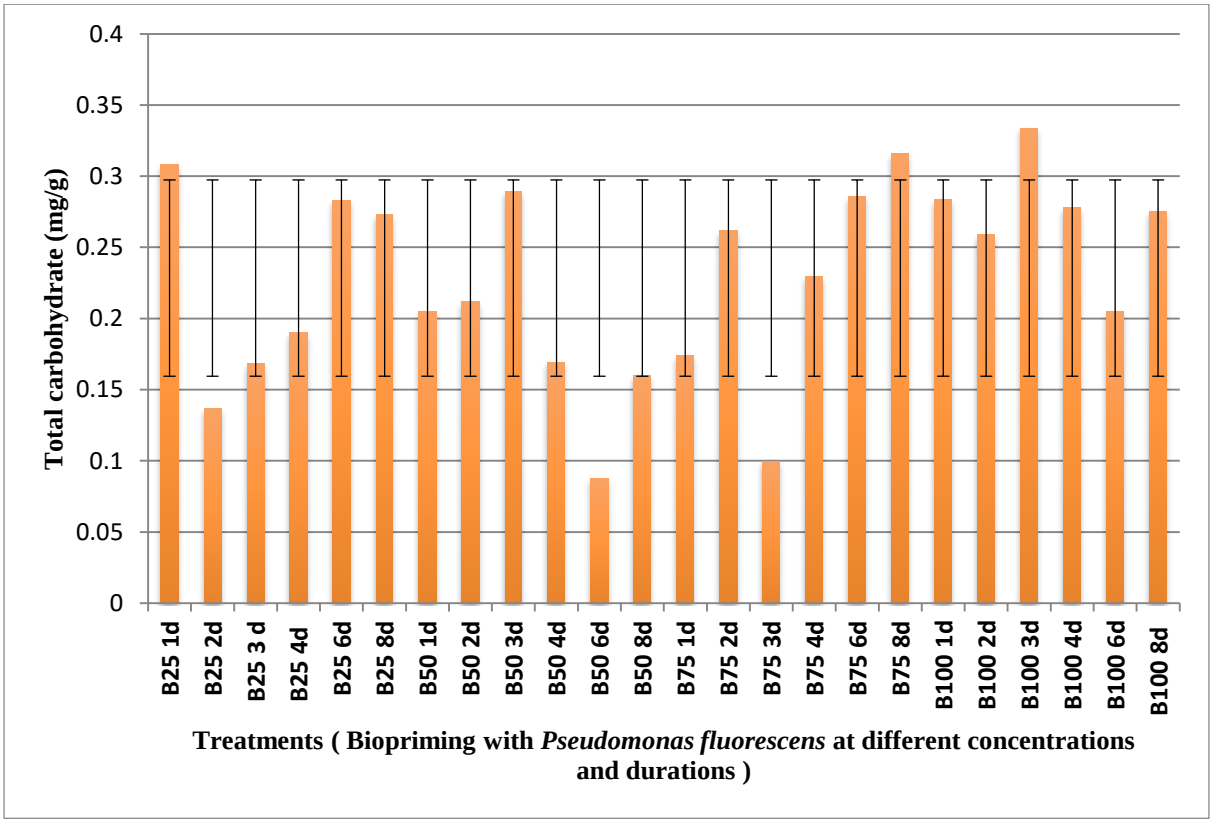

Fig 7 Effect of biopriming with *Pseudomonas fluorescens* on the total carbohydrate content of sandal seeds

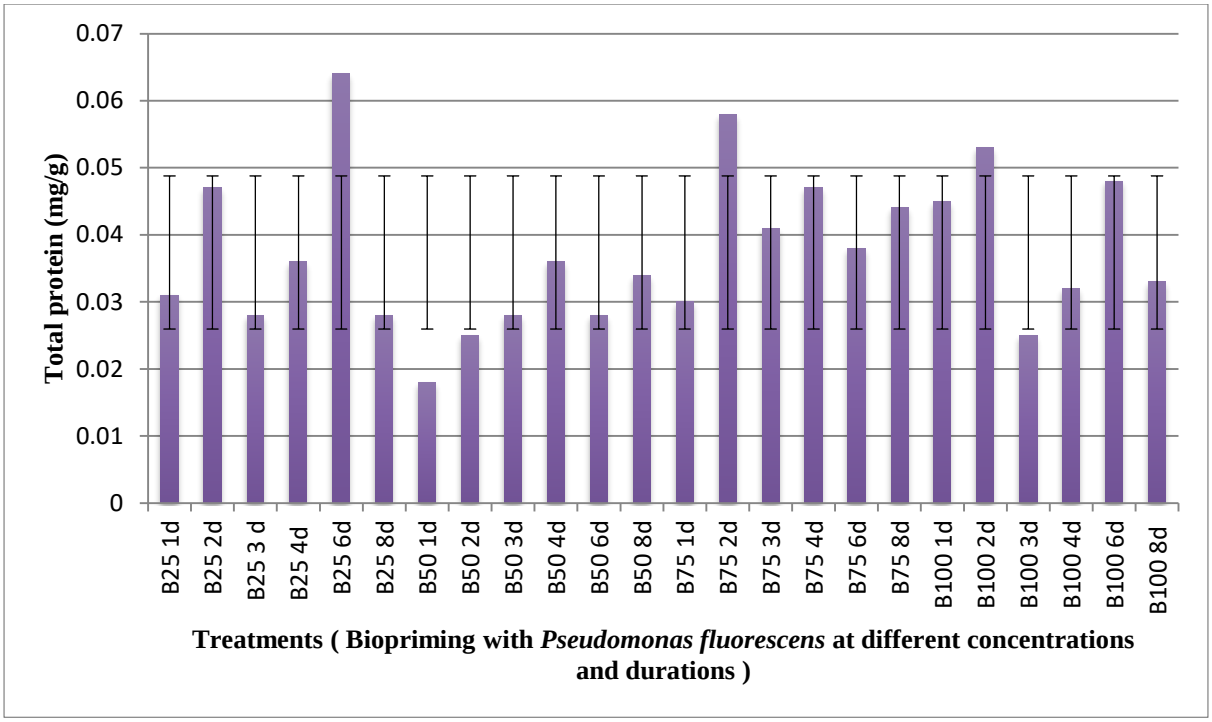

Fig 8 Effect of biopriming with *Pseudomonas fluorescens* on the total protein content of sandal seeds

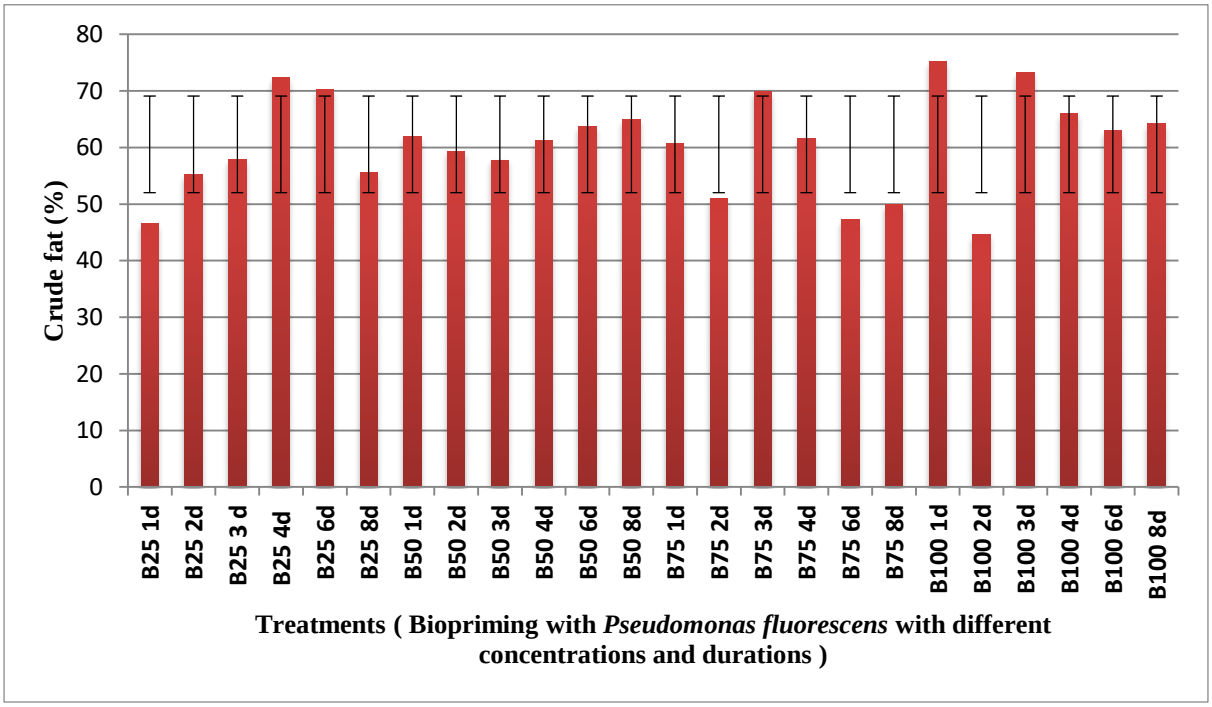

Fig 9 Effect of biopriming with *Pseudomonas fluorescens* on the crude fat content of sandal seeds.

The interaction effect between concentration and duration of bioinoculant was significant in carbohydrate ($F= 225.918$, $p < 0.01$) protein ($F= 69.140$, $p < 0.01$) and fat ($F= 27.056$, $p < 0.01$).

4.4.2. Biopriming with *Trichoderma viride*

The variation in total carbohydrate, protein and fat content of the seeds subjected to biopriming with *T viride* at different concentrations and durations is given in Fig 10-12.The highest carbohydrate content was observed for seeds bioprimed at 25% concentration for 3 days (0.722 mg g-1) and the lowest was at 75% for 2 days. (0.110 mg g-1). The seeds subjected to biopriming at 100% for 1day recorded the highest protein content (0.059 mg g-1) and the lowest was in the biopriming at 25% for 1 day. (0.020 mg g-1). The highest total fat was observed in seeds subjected to biopriming at 100% for 6 days (76.6%) and the lowest was at 75% for 1 day (34%)

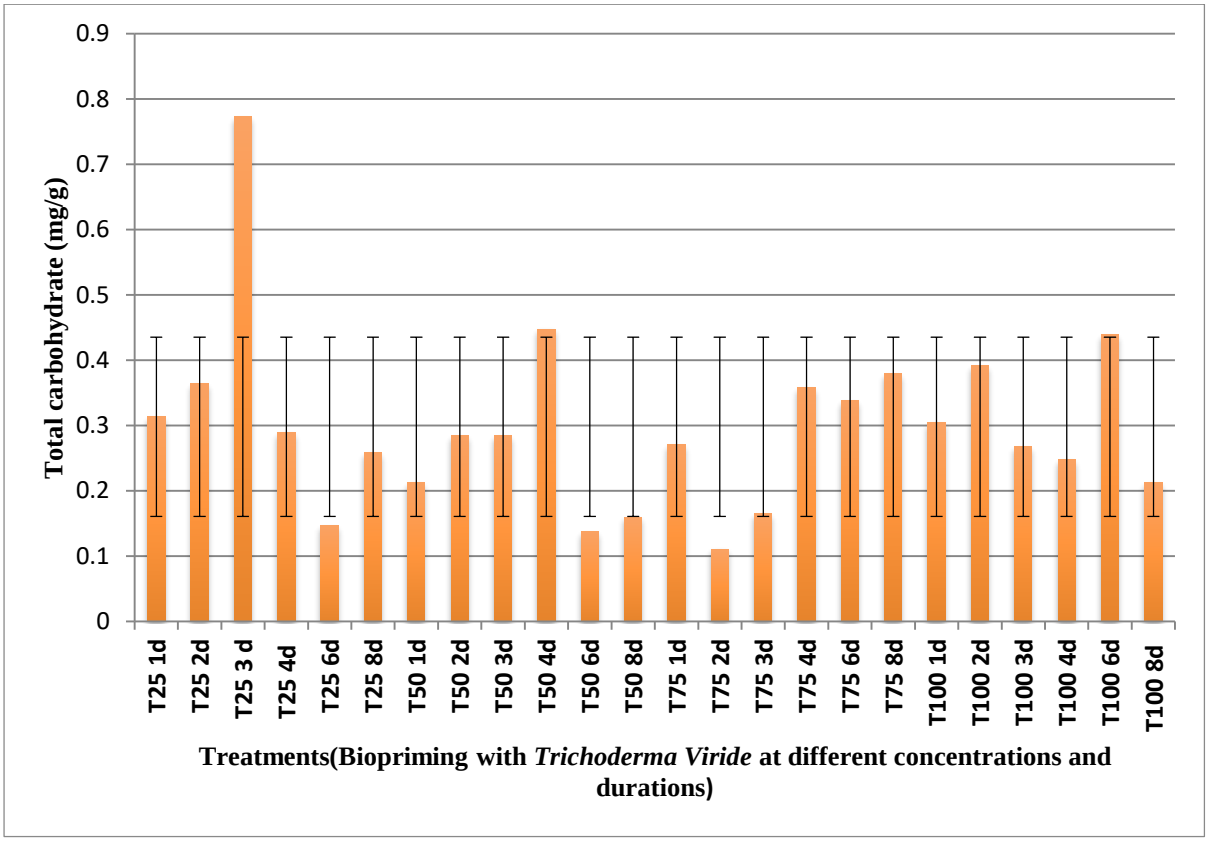

Fig 10 Effect of biopriming with *Trichoderma viride* on the total carbohydrate content of sandal seeds

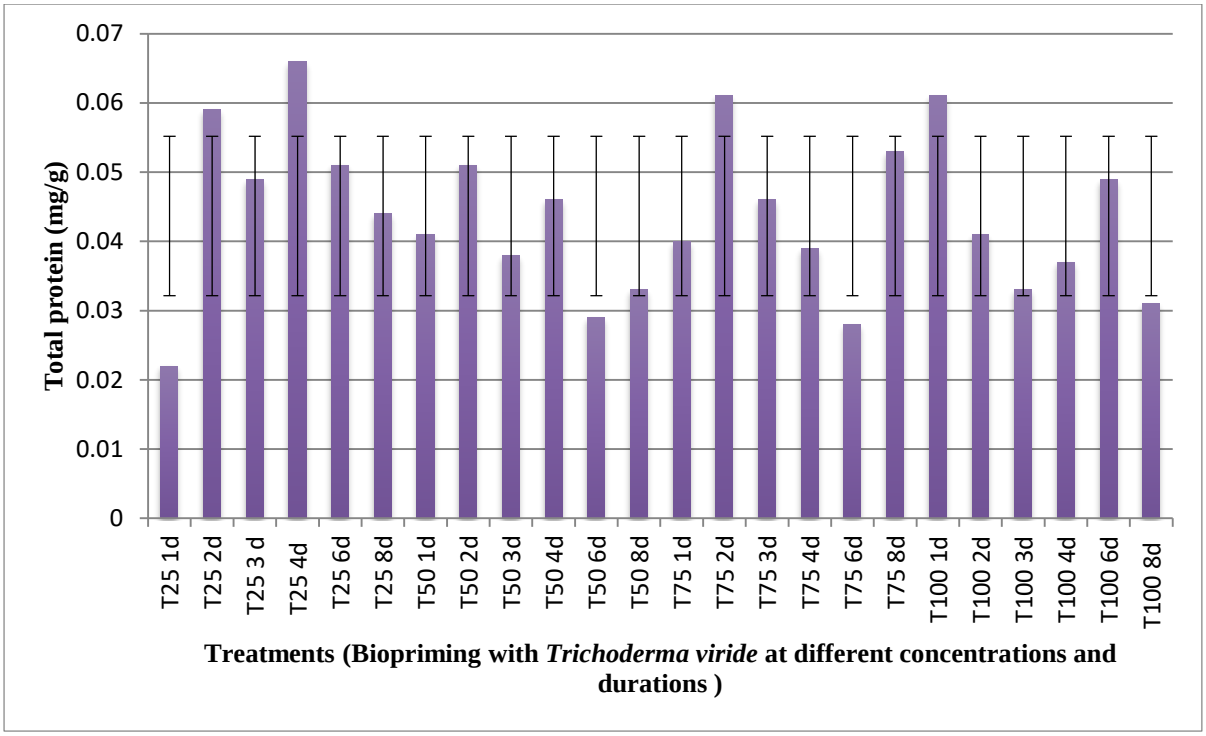

Fig 11 Effect of biopriming with *Trichoderma viride* on the total protein content of sandal seeds

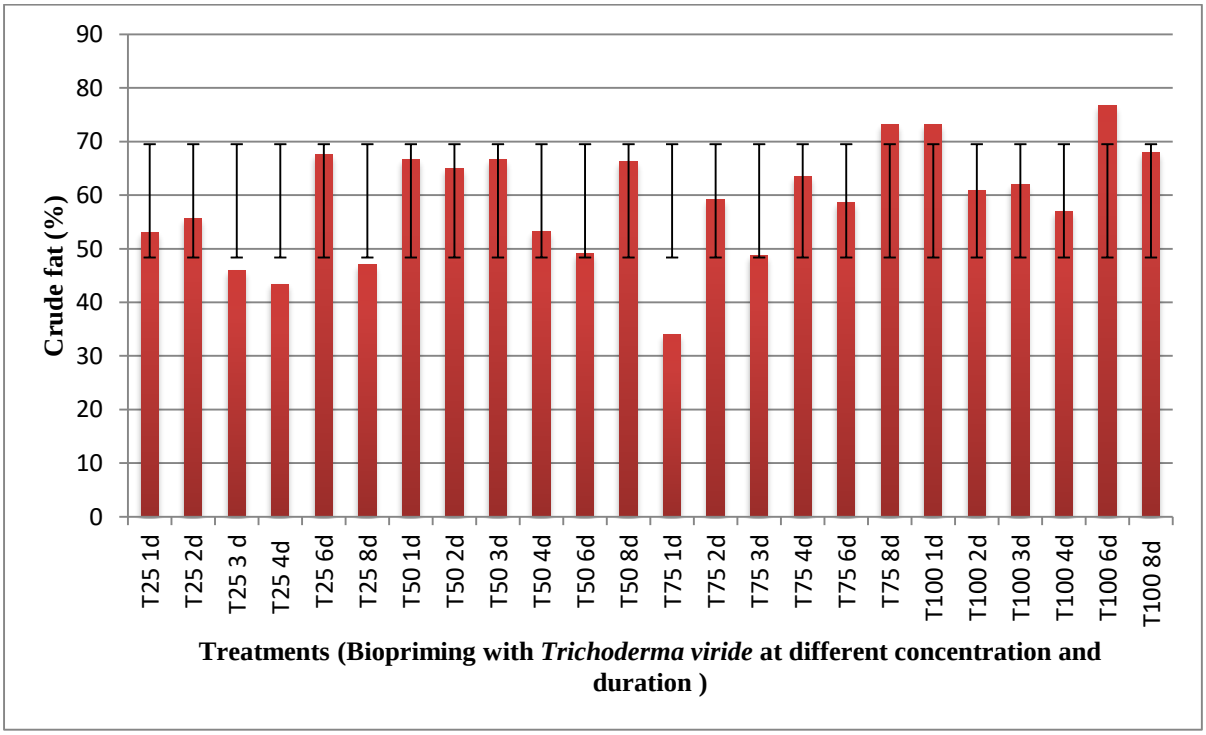

Fig 12 Effect of biopriming with *Trichoderma viride* on the crude fat content of sandal seeds

The statistical analysis revealed significant difference in carbohydrate ($F= 976.937$, $p < 0.01$),

Protein (F= 110.975, p < 0.01) and fat content (F= 32.460, p < 0.01) due to interaction effect of treatment concentration and duration.

4.4.3. Biopriming with PGPR II

The variation in total carbohydrate, protein and fat content of seeds subjected to biopriming with PGPR II is given in Fig 13-15 .The highest carbohydrate content was observed for seeds subjected to biopriming at 100% concentration for 1 day (0.370 mg g^{-1}) and the lowest was at 75% for 4 days (0.127 mg g^{-1}). Seeds subjected to biopriming treatment for 25 % for 4 days (0.077 mg g^{-1}) recorded the highest protein content and the lowest was in biopriming at 75% for 3 days (0.03 mg g^{-1}). The total fat content of seeds ranged from 44.6 % to 74 % and the highest value was observed for seeds subjected to biopriming treatment for 25% for 2 days (74%) and the lowest was for the seeds subjected to biopriming at 75% for 6 days (44.6%).

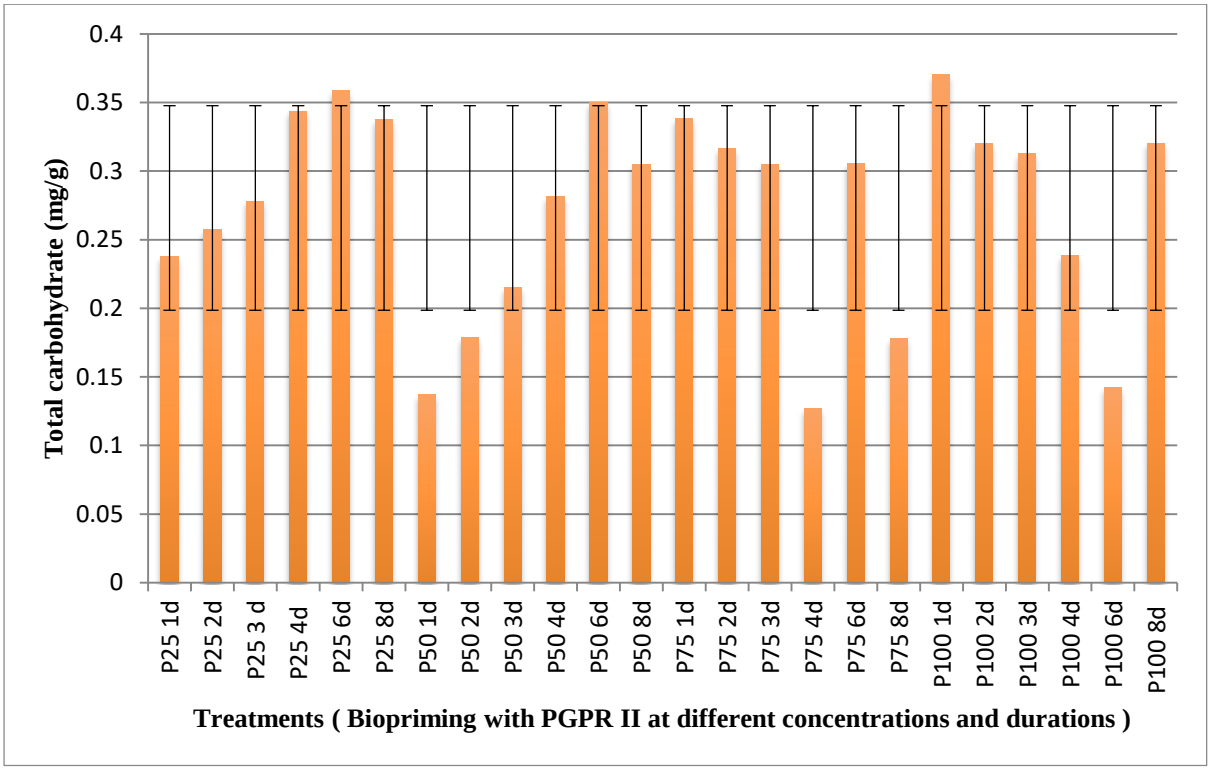

Fig 13 Effect of biopriming with PGPR II on the total carbohydrate content of sandal seeds

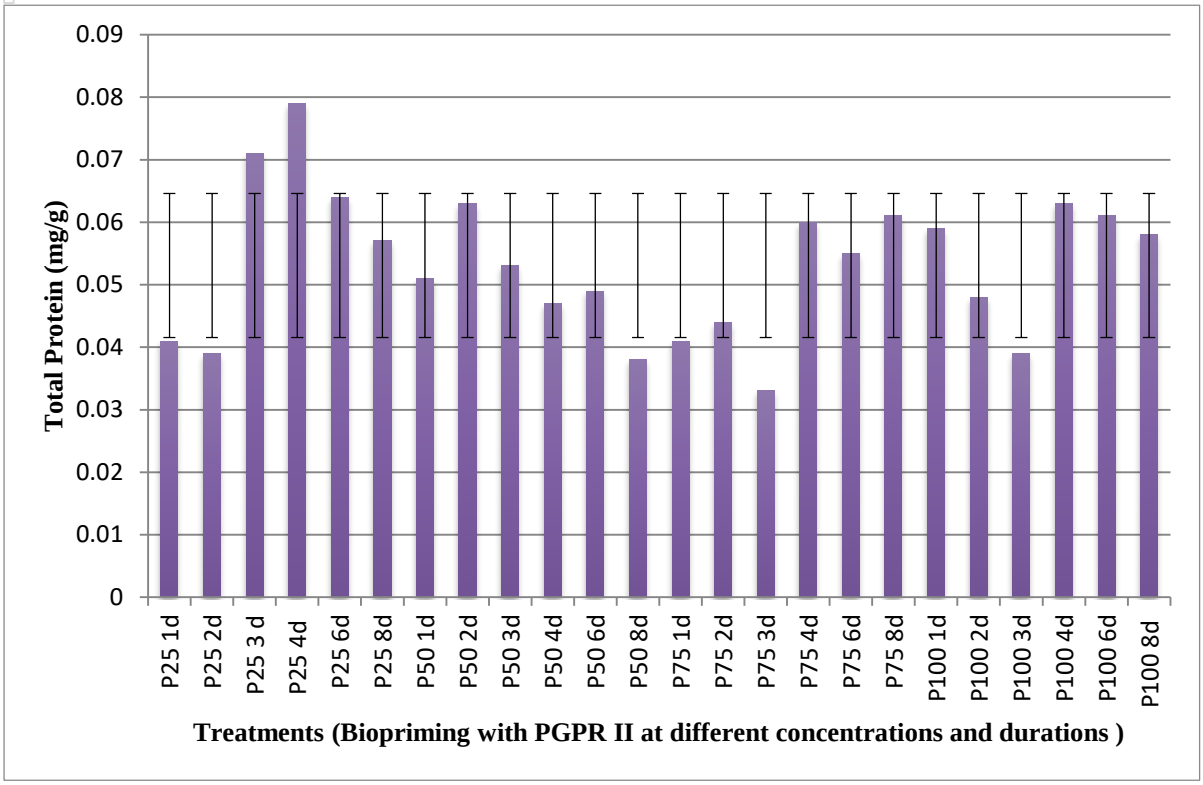

Fig 14 Effect of biopriming with PGPR II on the total protein content of sandal seeds

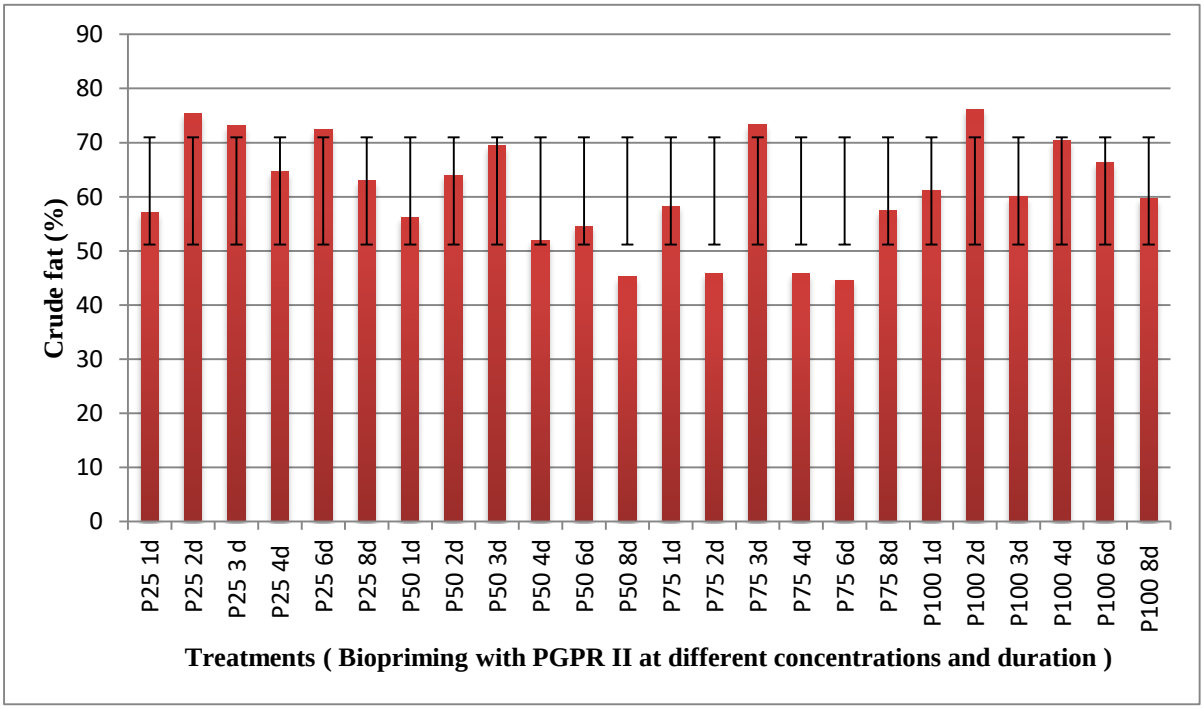

Fig 15 Effect of biopriming with PGPR II on the crude fat content of sandal seeds

Analysis of variance revealed significant difference in carbohydrate ($F= 310.594$, $p < 0.01$), protein ($F= 102.167$, $p < 0.01$) and fat content ($F= 25.153$, $p < 0.01$) of the seeds due to interaction effect between concentration and duration of bioinoculant.

4.4.4. The Effect of hydropriming on the biochemical content of the sandal seeds

The variation in total carbohydrate, protein and fat content of sandal seeds subjected to hydro priming is given in Fig 16-18. The highest value of total carbohydrate content was observed for seeds subjected to hydropriming for 6 days (0.394 mg g^{-1}) and the lowest was for 4 days (0.168 mg g^{-1}). The highest protein content was observed for seeds subjected to hydropriming for 8 days (0.042 mg g^{-1}) and the lowest was for the 1 day duration (0.028 mg g^{-1}). The fat content ranged from 42.0% to 52.4% and the highest value was observed for seeds subjected to hydropriming for 3 days (52.4%) and the lowest was for the seeds subjected to hydropriming for 2 days (42.0%).

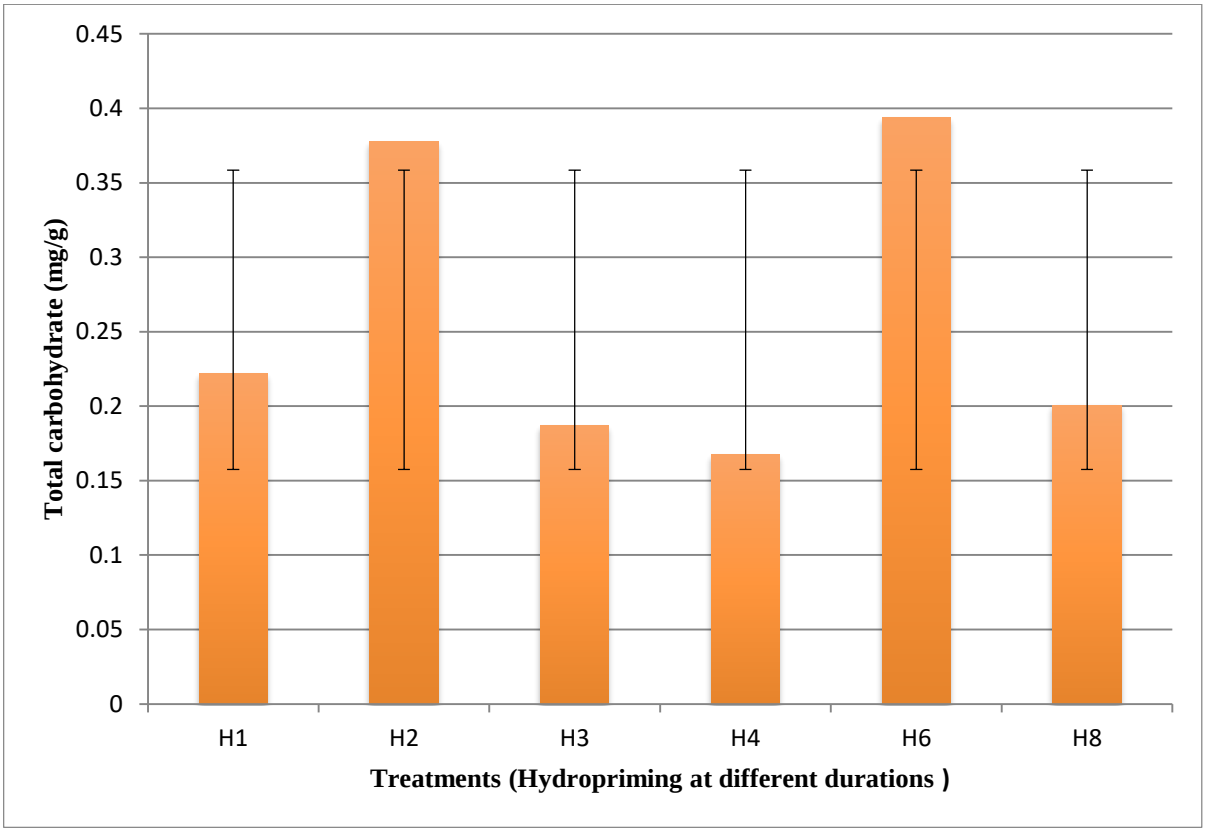

Fig 16 Effect of hydropriming on the total carbohydrate content of sandal seeds

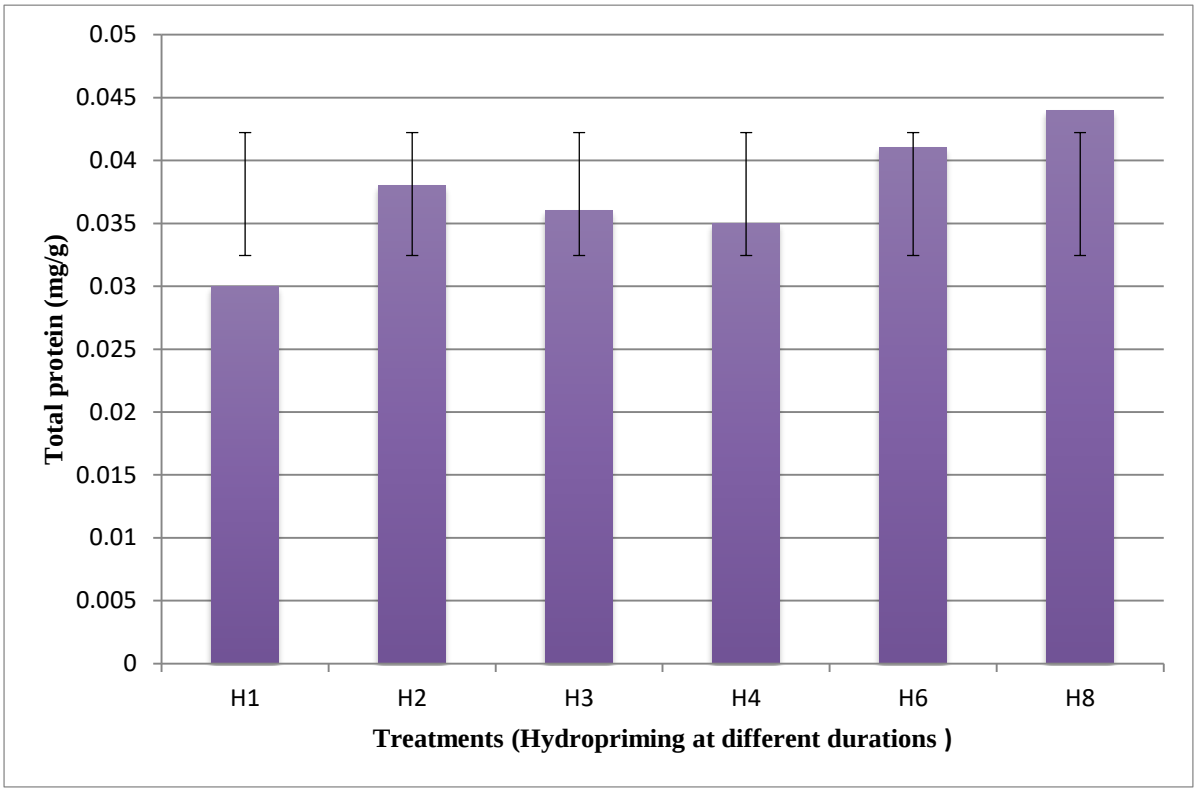

Fig.17 Effect of hydropriming on the total protein content of sandal seeds

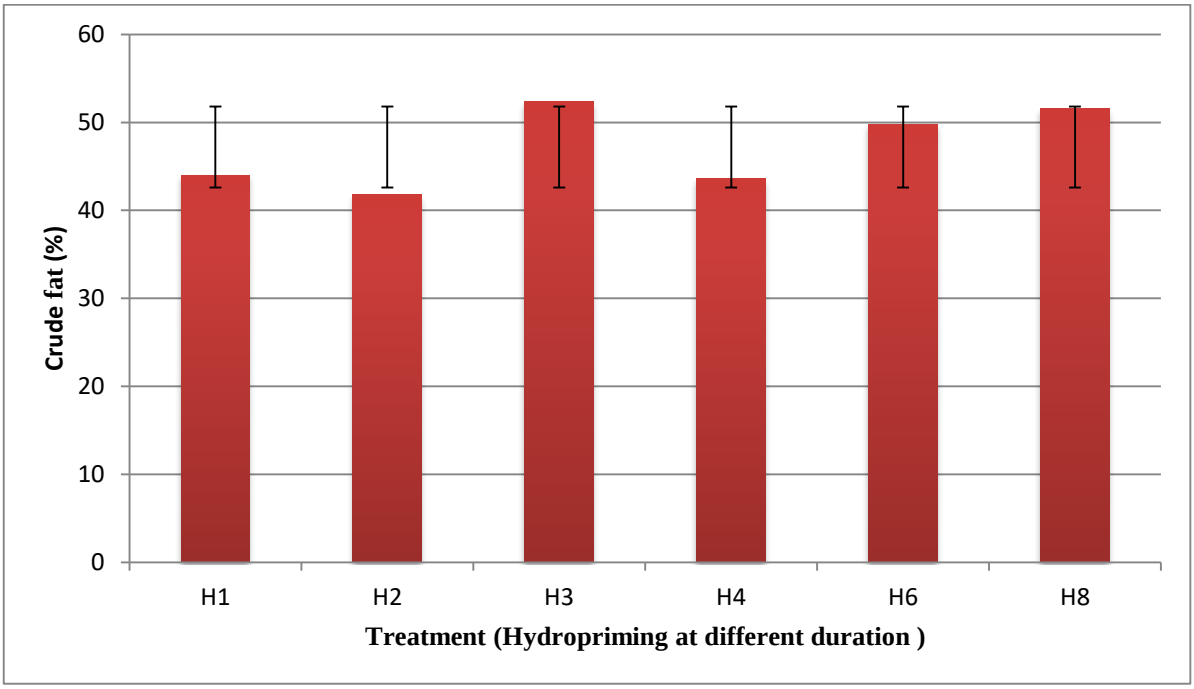

Fig 18 Effect of hydropriming on the crude fat content of sandal seeds

Analysis of variance revealed significant difference in carbohydrate ($F=17.9$, $p < 0.01$), protein ($F=2234.709$, $p < 0.01$) and fat content ($F= 25.153$, $p < 0.01$) of the seeds due to interaction effect of concentrations and durations of bioinoculant.

4.5. The effect of various priming treatments on the seedling performance of the sandal seeds primed with bioinoculant and subjected to post priming storage of one week

4.5.1. Biopriming with *Pseudomonas fluorescens*

4.5.1.1. Seedling growth

Impact of biopriming with *Pseudomonas fluorescens* on the shoot growth parameters of sandal seedlings at 30 and 180 DAT are presented in Table 9. At 30 DAT, shoot height was highest in seedlings bioprimed at 50% for 1 day (18.93 cm) and the seeds bioprimed at 25% for 4 days (4.17 cm) recorded the lowest seedling height. At 180 DAT, seedlings bioprimed at 50% for 1 day (26.33 cm) recorded the highest value and the lowest was at 25% for 6 days (9.17 cm). During initial observation, the largest collar diameter was shown by seedlings bioprimed at 100% for 8days (1.98 mm) and the lowest was shown by seeds bioprimed at 100% for 3 days. (0.98 mm). Whereas, at sixth month, seeds bioprimed at 75% for 2 days (2.74 mm) recorded the highest collar diameter and the seeds bioprimed at 100 % for 3 days (2.11 mm) recorded the lowest value. While, the largest leaf number was shown by seedlings bioprimed at 75% for 8 days (19.33) and the lowest was shown by seeds bioprimed at 25 % for 6 days (8.67) at 30 DAT. At 180 DAT also, the seedlings bioprimed at 75% for 8 days (23.3) recorded the highest leaf number and the seeds bioprimed at 25% for 6 days (12.7) recorded the least value. The largest leaf area was recorded in seedlings bioprimed at 50 % for 2 days (8.62cm ^{2}) and the lowest was shown by seeds bioprimed at 75 % for 3 days (1.27 cm ^{2}) at 90DAT and at 180 DAT, seeds bioprimed at 100% for 3 days (6.00 cm $^{2)}$ and the seeds bioprimed at 50% for 3 days (4.09 cm ^{2}) recorded the lowest leaf area. On biopriming with *P. fluorescens* the largest root length was shown by seedlings bioprimed at 75% for 1 day (16.33 cm) and the lowest was shown by seeds bioprimed at 75% for 2 days (0.767 cm) at 30 DAT (Table 10). At sixth month, seedlings bioprimed at 75% for 3 days (15.43 cm) recorded the highest root length and the seedlings bioprimed at 75 % for 2 days (4.2 cm) recorded the lowest value. The seedlings bioprimed at 25% for 4 days (6.00) recorded the highest root numbers (Table 10) and the lowest was shown by seeds bioprimed at 50% for 4 days (2.00) at 30 DAT. At 6th month, seeds bioprimed at 25% for 4 days (11) recorded the highest number of roots and the seeds bioprimed at 100 % for 3 days (2.67) recorded the lowest value. The highest total seedling length was shown by seedlings bioprimed at 50% for 1 day (34.83 cm) and the lowest was in those at 25% for 4 days (5.77 cm) at 30 DAT. At 180 DAT, seedlings bioprimed at 50% for 1day (46.5 cm) recorded the highest total seedling length and the seeds bioprimed at 25% for 4 days (16.5 cm) recorded the least.

Analysis of variance revealed significant differences in shoot height ($F=57.410$, $p < 0.01$), collar diameter ($F=31.829$, $p < 0.01$), number of leaves ($F=73.514$, $p < 0.01$), leaf area ($F=7.565$, $p < 0.01$), root length $F=67.488$, $p< 0.01$), number of roots ($F=10.044$, $p < 0.01$) and total seedling length ($F=95.806$, $p < 0.01$) at 30 DAT. At 180 DAT also the interaction effect between concentration and duration was significant in shoot height ($F=189.501$, $p < 0.01$), collar diameter ($F=94.179$, $p < 0.01$) , number of leaves, ($F=113.178$, $p < 0.01$), leaf area ($F=7.079$, $p < 0.01$), root length ($F=109.932$, $p < 0.01$), number of roots ($F=12.952$, $p < 0.01$) and total seedling length ($F=238.657$, $p <0.01$).

Table 9 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Pseudomonas fluorescens		Shoot Height (cm)		Collar Girth (mm)		Number of Leaves		Leaf Area (cm^2)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	15.70^{h}	23.13^{h}	1.46^{bcd}	2.59^{bcd}	16.67^{def}	20.70^{def}	6.31^{bcd}	7.79^{bc}
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	4.17^{bc}	11.57^{bc}	1.35^{bcd}	2.48^{bcd}	15.00^{cdef}	19.00^{cdef}	3.96^{abcd}	5.73^{ab}
	6	1.77^{ab}	9.17^{b}	1.48^{bcd}	2.61^{bcd}	8.67^{b}	12.70^{b}	2.60^{abc}	4.87^{bc}
	8	-	-	-	-	-	-	-	-
50%	1	18.93^{i}	26.33^{i}	1.58^{bcd}	2.71^{bcd}	17.00^{def}	21.00^{def}	4.16^{abcd}	6.30^{abc}
	2	7.73^{defg}	15.13^{defg}	1.48^{bcd}	2.61^{bcd}	10.33^{bc}	14.30^{bc}	8.62^{d}	9.34^{abc}
	3	7.80^{defg}	15.20^{defg}	1.21^{bc}	2.34^{bc}	18.67^{ef}	22.70^{ef}	3.92^{abcd}	4.09^{bc}
	4	6.50^{cdef}	13.90^{cdef}	1.78^{cd}	2.91^{cd}	18.33^{ef}	22.30^{ef}	5.48^{abcd}	7.20^{bc}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
75%	1	14.90^{f}	22.30^{h}	1.57^{bcd}	2.70^{bcd}	17.33^{def}	21.30^{def}	5.84^{abcd}	6.56^{abc}
	2	5.63^{cde}	13.03^{cde}	1.61^{bcd}	2.74^{bcd}	17.00^{def}	21.00^{def}	5.71^{abcd}	6.4^{abc}
	3	9.00^{fg}	16.40^{fg}	1.28^{bcd}	2.41^{bcd}	16.33^{def}	20.30^{def}	1.27^{ab}	4.03^{ab}
	4	8.90^{fg}	16.30^{fg}	1.57^{bcd}	2.70^{bcd}	18.00^{ef}	22.00^{ef}	5.83^{abcd}	8.76^{c}
	6	-	-	-	-	-	-	-	-
	8	9.70^{g}	17.1^{g}	1.82^{cd}	2.95cd	19.33^{f}	23.30^{f}	3.41^{abcd}	5.93^{abc}
100%	1	7.47^{defg}	14.87^{defg}	1.18^{bc}	2.31^{bc}	15.00^{cdef}	19.00^{cdef}	5.84^{abcd}	7.75^{bc}
	2	8.30^{efg}	15.70^{efg}	1.33^{bcd}	2.46^{bcd}	17.33^{def}	21.30^{def}	3.04^{abcd}	5.08^{bc}
	3	8.47^{efg}	15.70^{efg}	0.98^{b}	2.11^{b}	12.33^{bcd}	16.30^{bcd}	6.00^{bcd}	9.35^{ab}
	4	-	-	-	-	-	-	-	-
	6	4.90^{cd}	12.30^{cd}	1.08^{bc}	2.21^{bc}	18.67^{ef}	22.70^{ef}	7.31^{cd}	8.81^{abc}
	8	8.90^{fg}	16.30^{fg}	1.98^{d}	3.11^{d}	13.67^{bcde}	17.70^{bcde}	6.81^{bcd}	7.09^{bc}
SEM		0.539	0.538	0.137	0.137	0.928	0.928	1.07	1.22
Main effects									

Concentration								
25%	3.610^{A}	7.31^{A}	0.827^{A}	1.28^{A}	6.72^{A}	8.72^{A}	2.86^{A}	4.48^{A}
50%	6.83^{B}	11.76^{B}	1.009^{B}	1.76^{B}	10.72^{B}	13.39^{B}	4.57^{B}	5.66^{A}
75%	8.02^{C}	14.19^{C}	1.309^{C}	2.25^{D}	14.67^{D}	16.17^{C}	4.39^{AB}	6.52^{B}
100%	6.34^{B}	12.51^{B}	1.092^{B}	2.03^{C}	12.83^{C}	18^{D}	4.84^{B}	7.67^{B}
SEM	0.22	0.22	0.0561	0.0561	0.379	0.379	0.437	0.498
Duration								
1	14.25^{D}	21.66^{E}	1.448^{D}	2.58^{E}	16.5^{C}	20.5^{C}	5.29^{B}	8.33^{B}
2	5.42^{BC}	10.97^{CD}	1.107^{BC}	1.95^{CD}	11.17^{B}	14.17^{B}	4.34^{AB}	6.06^{AB}
3	6.32^{C}	11.87^{D}	0.868^{AB}	1.72^{BC}	11.83^{B}	14.83^{B}	2.80^{A}	4.92^{A}
4	4.89^{B}	10.44^{C}	1.174^{CD}	2.02^{D}	12.83^{B}	15.83^{B}	3.82^{AB}	6.73^{AB}
6	1.67^{A}	5.37^{A}	0.640^{A}	1.21^{A}	6.83^{A}	8.83^{A}	2.23^{A}	4.71^{AB}
8	4.65^{B}	8.35^{B}	0.951^{BC}	1.52^{B}	8.25^{A}	10.25^{A}	2.57^{A}	4.61^{AB}
SEM	0.27	0.269	0.0687	0.0687	0.464	0.464	0.536	0.498
Values within the same column with similar superscripts are homogenous								

Table 10 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Pseudomonas fluorescens		Root Length (cm)		Number of Lateral Roots		Total Seedling Length	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	8.20^{def}	12.50^{efgh}	4.67^{bc}	8.00^{bcd}	23.90^{h}	35.60^{i}
	2	-	-	-	-	-	-
	3	-	-	-	-	-	-

	4	1.60^{ab}	6.11^{bc}	6.00^{c}	11.00^{d}	5.77^{b}	16.50^{b}
	6	7.10^{d}	12.61^{ef}	4.33^{bc}	7.33^{bcd}	8.87^{bc}	20.60^{bcd}
	8	-	-	-	-	-	-
50%	1	15.90^{h}	20.20^{i}	3.67^{abc}	6.67^{bcd}	34.83^{i}	46.50^{i}
	2	10.57^{efg}	14.87^{ghi}	4.33^{bc}	6.67^{bcd}	18.30^{fg}	30.00^{gh}
	3	2.93^{ab}	5.23^{bc}	3.33^{abc}	4.67^{abc}	8.73^{bc}	20.40^{bcd}
	4	11.77^{g}	16.07^{i}	2.00^{ab}	3.67^{ab}	18.27^{fg}	30.00^{gh}
	6	-	-	-	-	-	-
	8	-	-	-	-	-	-
75%	1	16.33^{h}	20.63^{ib}	4.33^{bc}	6.33^{bcd}	31.23^{i}	42.90^{i}
	2	0.77^{ab}	4.20^{b}	3.00^{abc}	5.00^{abc}	6.40^{b}	17.20^{bc}
	3	11.13^{fg}	15.43^{hi}	3.00^{abc}	5.00^{abc}	20.13^{gh}	31.80^{hi}
	4	7.60^{de}	11.90^{efg}	4.67^{bc}	6.67^{bcd}	16.50^{efg}	28.20^{fgh}
	6	-	-	-	-	-	-
	8	10.37^{efg}	14.67^{fghi}	6.33^{c}	10.00^{cd}	20.07^{gh}	31.80^{hi}
100%	1	6.13^{cd}	10.43^{de}	2.67^{abc}	4.33^{ab}	13.60^{de}	25.30^{ef}
	2	6.20^{cd}	10.50^{de}	2.67^{abc}	3.33^{ab}	14.50^{def}	26.20^{efg}
	3	1.60^{ab}	5.90^{bc}	2.67^{abc}	2.67^{ab}	10.07^{bcd}	21.80^{cde}
	4	-	-	-	-	-	-
	6	2.23^{ab}	6.53^{bc}	3.00^{abc}	4.33^{ab}	7.13^{b}	18.80^{bc}
	8	3.80^{bc}	8.10^{cd}	4.33^{bc}	5.67^{bcd}	12.70^{cde}	24.40^{def}
SEM		0.569	0.3	0.726	1.03	0.816	0.846
Main effects							
Concentration							
25%		2.82^{A}	4.80^{A}	2.50^{AB}	4.39^{AB}	6.42^{A}	12.1^{A}
50%		6.53^{B}	9.39^{C}	2.22^{A}	3.61^{A}	13.36^{C}	21.2^{C}
75%		7.70^{C}	11.14^{D}	3.56^{B}	5.50^{B}	15.72^{D}	26^{D}
100%		3.33^{A}	6.91^{B}	2.56^{AB}	3.39^{A}	9.67^{B}	20.1^{B}
SEM		0.232	0.245	0.297	0.419	0.333	0.345
Duration							
1		11.64^{D}	15.94^{E}	3.83^{B}	6.33^{C}	25.89^{D}	37.6^{D}

2	4.38^{BC}	7.39^{CD}	2.50^{AB}	3.75^{AB}	9.80^{BC}	18.36^{C}
3	3.42^{AB}	6.64^{BC}	2.25^{A}	3.08^{A}	9.73^{BC}	18.51^{C}
4	5.24^{C}	8.22^{D}	3.17^{AB}	5.33^{BC}	10.13^{C}	18.66^{C}
6	2.33^{A}	4.48^{A}	1.83^{A}	2.92^{A}	4.00^{A}	9.85^{A}
8	3.54^{B}	5.69^{AB}	2.67^{A}	3.92^{AB}	8.19^{B}	10.04^{B}
SEM	0.285	0.3	0.363	0.419	0.408	0.423
Values within the same column with similar superscripts are homogenous						

4.5.1.2. Biomass production

Variation in fresh weight of seedlings bioprimed with *Pseudomonas fluorescens* at different duration and concentration on are presented in Table 11. Analysis of variance revealed significant difference in fresh weight of stem ($F=13.499$, $p < 0.01$) leaf ($F=89.165$, $p < 0.01$), root ($F=43.411$, $p < 0.01$) and total plant ($F=97.437$, $p < 0.01$) at 90 DAT. At 180 DAT also fresh weight of leaf ($F=100.925$, $p < 0.01$), root ($F=46.037$, $p < 0.01$) and total plant ($F=106.062$, $p < 0.01$) varied significantly. But the interaction effect was not significant in stem fresh weight however, duration of the treatment ($F=36.431$, $p < 0.01$) and the concentration of the bioinoculant ($F=17.920$, $p < 0.01$) varied significantly.

For the first month of observation the largest stem fresh weight was shown by seedlings bioprimed at 50% for 1 day (1.00 g) and the lowest was by those at 25% for 4 days (0.107 g). At sixth month, seeds bioprimed at 50% for 1 day (1.99 g) recorded the highest stem fresh weight and the seeds bioprimed at 25% for 4 days (0.103 g) recorded the lowest weight. At 30 DAT, the largest leaf fresh weight was shown by seedlings bioprimed at 50% for 1 day (1.350 g) and the lowest was shown those at 50 % for 2 days (0.107 g). At 180 DAT, seedlings bioprimed at 50% for 1 day (1.432 g) recorded the highest leaf fresh weight and the seeds bioprimed at 50% for 2 days (0.177 g) recorded the lowest value. For the first month of observation the largest root fresh weight was recorded by seedlings bioprimed at 25% for 1 day (1.36 g) and lowest was on biopriming at 25% for 4 days (0.05 g). At 180 DAT also, seeds bioprimed at 25% for 1 day (1.39 g) recorded the highest root fresh weight and biopriming at 50 % for 2 days (0.067g) recorded the lowest value. The largest total fresh weight at 30 DAT was shown by seedlings bioprimed at 50% for 1 day (3.043 g) and the lowest value was on biopriming at 25% for 4 days (0.323 g). At sixth month also, seedlings bioprimed at 50% for 1 day (3.133 g) recorded the highest fresh weight and the seeds bioprimed at 25% for 4 days (0.413 g) recorded the lowest value.

Variation in dry weight of the seedlings bioprimed with *P. fluorescens* with concentration and duration are presented in Table12. During first month of observation, the largest stem dry weight is shown by seedlings bioprimed at 75% for 2 days (0.2844 g) and the lowest value was shown by seeds bioprimed at 25% for 3 days (0.071 g). At sixth month, seeds bioprimed at 100% for 1 day recorded the highest stem dry weight (0.81 g)) and the seeds bioprimed at 25% for 3 days (0.083 g) recorded the lowest stem dry weight. The largest leaf dry weight at 30 DAT was shown by seedlings bioprimed at 75% for 2 days (0.873 g) and lowest was on biopriming at 50% for 1 day (0.071 g). At 180 DAT, seedlings bioprimed at 75% for 2 days (0.906 g) recorded the highest leaf dry weight and those at 50% for 1 day (0.083 g) recorded the lowest leaf dry weight. For the first month of observation the largest dry weight (roots) was shown by seedlings bioprimed at 25% for 8days (0.3467 g) and the lowest dry weight (roots) was shown by seeds bioprimed at 50% for 1day (0.02 g). At sixth month, seeds bioprimed at 25% for 8 days (0.3467 g) recorded the highest dry weight and the seeds bioprimed at 50% for 1 day recorded the lowest value (0.03 g) .The highest total plant dry weight was shown by seedlings bioprimed at 25% for 8 days (2.029 g) and the lowest dry weight was shown by seeds bioprimed at 25 % for 3 days (0.216 g) at 30 DAT. At sixth month, seeds bioprimed at 25% for 8 days (2.39 g) recorded the highest dry weight and at 25 % for 4 days (0.227 g) recorded the lowest dry weight.

There was significant difference in dry weight of the stem ($F=13.237$, $p < 0.01$), leaf ($F=88.163$, $p < 0.01$), root ($F=45.850$, $p < 0.01$) and total dry weight($F=97.988$, $p < 0.01$) at 90 DAT and at 180 DAT fresh

weight of leaf ($F=21.182$, $p < 0.01$), root ($F=12.906$, $p < 0.01$) and total plant ($F=26.741$, $p < 0.01$) varied due to interaction between bioinoculant concentration and duration. But the interaction effect was not significant in stem dry weight at 180 days however, duration of the treatment ($F=19.959$, $p < 0.01$) and the concentration of the bioinoculant ($F=7.629$, $p< 0.01$) varied significantly.

Table 11 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Pseudomonas florescence		Fresh weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	1.250^{h}	1.320^{i}	0.273^{bcd}	0.293^{abc}	1.360^{h}	1.390^{h}	2.883^{i}	2.973^{i}
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	0.167^{a}	0.237^{b}	0.107^{ab}	0.103^{ab}	0.050^{ab}	0.080^{ab}	0.323^{bc}	0.413^{b}
	6	0.660^{g}	0.780^{fgh}	0.184^{bcd}	0.221^{a}	0.100^{abcd}	0.123^{abcd}	0.723^{fg}	0.978^{efg}
	8	-	-	-	-	-	-	-	-
50%	1	1.350^{h}	1.420^{i}	1.000^{e}	1.990^{d}	0.693^{g}	0.723^{g}	3.043^{i}	3.133^{is}
	2	0.107^{a}	0.177^{ab}	0.213^{abcd}	0.243^{abc}	0.037^{ab}	0.067^{ab}	0.357^{ab}	0.447^{b}
	3	0.803^{efg}	0.873^{fgh}	0.207^{abcd}	0.267^{bc}	0.200^{abcd}	0.230^{bcd}	1.280^{ef}	1.370^{ef}
	4	0.670^{def}	0.740^{efg}	0.217^{abcd}	0.237^{abc}	0.460^{ef}	0.490^{ef}	1.347^{f}	1.437^{f}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
75%	1	0.570^{cd}	0.640^{de}	0.377^{cd}	0.397^{bc}	0.223^{bcd}	0.253^{bcd}	1.170^{def}	1.260^{def}
	2	0.403^{bc}	0.473^{cd}	0.187^{abcd}	0.195^{abc}	0.207^{abcd}	0.237^{bcd}	0.807^{cd}	0.897^{cd}
	3	1.310^{h}	1.380^{i}	0.427^{d}	0.521^{c}	0.313^{cde}	0.343^{cde}	2.050^{h}	2.140^{h}
	4	0.597^{cde}	0.667^{def}	0.197^{abcd}	0.297^{abc}	0.343^{de}	0.373^{de}	1.137^{def}	1.227^{def}
	6	-	-	-	-	-	-	-	-
	8	0.990^{g}	1.060^{h}	0.277^{bcd}	0.367^{bc}	0.200^{abcd}	0.230^{bcd}	1.467^{fg}	1.557^{fg}
100%	1	0.827^{fg}	0.897^{gh}	0.307^{cd}	0.397^{bc}	0.670^{fg}	0.700^{fg}	1.803^{gh}	1.893^{gh}
	2	$0.477c^{d}$	0.547^{de}	0.110^{abc}	0.119^{ab}	0.183^{abcd}	0.213^{fg}	0.770^{cd}	0.860^{cd}
	3	0.497^{cd}	0.567^{de}	0.207^{abcd}	0.219^{abc}	0.230^{bcd}	0.260^{bcd}	0.933^{de}	1.023^{de}
	4	-	-	-	-	-	-	-	-
	6	0.647^{def}	0.717^{efg}	0.277^{bcd}	0.298^{bc}	0.347^{de}	0.377^{de}	1.270^{ef}	1.360^{ef}
	8	0.493^{cd}	0.563^{de}	0.173^{abcd}	0.197^{abc}	0.210^{abcd}	0.240^{bcd}	0.877^{cde}	0.967^{cde}
SEM		0.0416	0.0416	0.049	0.0485	0.0393	0.0393	0.0743	0.0743
Main effects									

Concentration								
25%	0.274^{A}	0.309^{A}	0.089^{A}	0.089^{A}	0.255^{A}	0.270^{A}	0.618^{A}	0.663^{A}
50%	0.488^{B}	0.535^{B}	0.284^{C}	0.298^{C}	0.232^{A}	0.252^{A}	1.004^{BC}	1.064^{B}
75%	0.645^{C}	0.703^{C}	0.246^{BC}	0.277^{BC}	0.214^{A}	0.239^{A}	1.105^{C}	1.180^{C}
100%	0.490^{B}	0.548^{B}	0.179^{B}	0.192^{B}	0.273^{A}	0.298^{A}	0.942^{B}	1.017^{B}
SEM	0.017	0.017	0.02	0.0198	0.016	0.016	0.0303	0.0303
Duration								
1	0.999^{D}	1.069^{D}	0.489^{C}	0.497^{C}	0.737^{D}	0.767^{D}	2.225^{D}	2.315^{D}
2	0.247^{A}	0.299^{A}	0.130^{AB}	0.145^{AB}	0.107^{AB}	0.129^{AB}	0.483^{A}	0.551^{A}
3	0.652^{C}	0.705^{C}	0.228^{B}	0.320^{B}	0.186^{BC}	0.208^{BC}	1.066^{C}	1.133^{C}
4	0.358^{B}	0.4110^{B}	0.130^{AB}	0.145^{AB}	0.213^{C}	0.236^{C}	0.702^{B}	0.769^{B}
6	0.218^{A}	0.253^{A}	0.108^{A}	0.113^{A}	0.117^{AB}	0.132^{AB}	0.443^{A}	0.488^{A}
8	0.371^{B}	0.406^{B}	0.112^{A}	0.117^{A}	0.102^{A}	0.117^{A}	0.586^{AB}	0.631^{AB}
SEM	0.0208	0.0208	0.0245	0.0249	0.0196	0.0196	0.0372	0.0372
Values within the same column with similar superscripts are homogenous								

Table 12 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Pseudomonas florescence		Dry weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
	1	0.111^{a}	0.123^{ab}	0.071^{ab}	0.083^{a}	0.025^{ab}	0.050^{abc}	0.216^{ab}	0.227^{ab}
	2	-	-	-	-	-	-	-	-

25%	3	-	-	-	-	-	-	-	-
	4	0.151^{ab}	0.163^{abcd}	0.104^{abc}	0.310^{a}	0.060^{abc}	0.067^{abc}	0.336^{bc}	0.422^{abc}
	6	0.227^{ab}	0.297^{bc}	0.157^{abc}	0.147^{ab}	0.120^{abc}	0.150^{abc}	0.503^{bc}	0.593^{bc}
	8	-	-	-	-	-	-	-	-
50%	1	0.551^{fg}	0.587^{gh}	0.667^{e}	0.764^{b}	0.347^{g}	0.377^{ef}	2.029^{a}	2.390^{i}
	2	0.071^{a}	0.083^{ab}	0.142^{abcd}	0.165^{a}	0.018^{ab}	0.031^{ab}	0.238^{ab}	0.243^{ab}
	3	0.536^{efg}	0.693^{efg}	0.185^{bcd}	0.194^{a}	0.100^{abcd}	0.113^{abcd}	0.853^{ef}	0.943^{cdef}
	4	0.447^{def}	0.569^{cdefg}	0.144^{abcd}	0.163^{a}	0.230^{ef}	0.242^{def}	0.898^{f}	0.973^{defg}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
75%	1	0.267^{bc}	0.353^{abc}	0.131^{abcd}	0.190^{a}	0.103^{abcd}	0.203^{abcd}	0.538^{cd}	0.647^{abcd}
	2	0.873^{h}	0.906^{gh}	0.284^{d}	0.334^{a}	0.157^{cde}	0.167^{abcd}	1.367^{h}	1.410^{fg}
	3	0.398^{cde}	0.367^{bcdef}	0.131^{abcd}	0.190^{a}	0.171^{de}	0.193^{cdef}	0.758^{def}	0.833^{bcdef}
	4	0.380^{cd}	0.396^{bcdef}	0.251^{cd}	0.270^{a}	0.112^{bcd}	0.140^{abcd}	0.780^{def}	0.917^{cdef}
	6	-	-	-	-	-	-	-	-
	8	0.551^{fg}	0.553^{gh}	0.204^{bcd}	0.244^{a}	0.335^{fg}	0.373^{f}	1.202^{gh}	1.217^{gh}
100%	1	0.318^{cd}	0.330^{bcde}	0.733^{abc}	0.810^{a}	0.092^{abcd}	0.133^{abcd}	0.538^{cd}	0.647^{bcde}
	2	0.331^{cd}	0.373^{defg}	0.138^{abcd}	0.157^{a}	0.115^{bcd}	0.167^{bcde}	0.650^{h}	1.367^{def}
	3	0.431^{def}	0.443^{cdefg}	0.184^{bcd}	0.201^{a}	0.173^{de}	0.177^{bcdef}	0.647^{ef}	0.847^{def}
	4	-	-	-	-	-	-	-	-
	6	0.329^{cd}	0.367^{bcdef}	0.116^{abcd}	0.136^{a}	0.105^{abcd}	0.113^{abcd}	0.450^{cde}	0.584^{bcde}
	8	0.493^{cd}	0.563^{de}	0.173^{abcd}	0.197^{abc}	0.210^{abcd}	0.240^{bcd}	0.877^{cde}	0.967^{cde}
SEM		0.0277	0.04	0.0327	0.0357	0.0196	0.0210	0.0495	0.069
Main effects									
Concentration									
25%		0.205^{A}	0.216^{A}	0.060^{A}	0.063^{A}	0.128^{A}	0.131^{A}	0.304^{A}	0.412^{A}
50%		0.348^{B}	0.368^{B}	0.190^{C}	0.240^{B}	0.116^{A}	0.119^{AB}	0.531^{BC}	0.670^{B}
75%		0.430^{C}	0.541^{BC}	0.164^{BC}	0.173^{B}	0.107^{A}	0.118^{AB}	0.451^{C}	0.737^{B}
100%		0.327^{B}	0.361^{C}	0.119^{B}	0.139^{AB}	0.137^{A}	0.152^{B}	0.481^{B}	0.628^{B}
SEM		0.0113	0.0263	0.0133	0.0195	0.00801	0.0113	0.0202	0.0261
Duration									

1	0.666^{D}	0.705^{C}	0.322^{C}	0.353^{B}	0.368^{D}	0.393^{B}	1.072^{D}	1.483^{C}
2	0.164^{A}	0.177^{A}	0.087^{AB}	0.097^{A}	0.053^{AB}	0.061^{A}	0.252^{A}	0.322^{A}
3	0.435^{C}	0.618^{B}	0.152^{B}	0.172^{A}	0.093^{BC}	0.103^{A}	0.515^{C}	0.711^{B}
4	0.239^{B}	0.287^{A}	0.087^{AB}	0.093^{A}	0.107^{C}	0.116^{A}	0.362^{B}	0.468^{A}
6	0.146^{A}	0.167^{A}	0.072^{A}	0.102^{A}	0.058^{AB}	0.061^{A}	0.235^{A}	0.296^{A}
8	0.247^{B}	0.266^{A}	0.075^{A}	0.093^{A}	0.051^{A}	0.059^{A}	0.293^{A}	0.391^{A}
SEM	0.0139	0.03	0.0163	0.0278	0.00981	0.0138	0.02	0.032
Values within the same column with similar superscripts are homogenous								

4.5.1.3. Plant Growth Analysis indices

The effect of biopriming concentration and duration on the plant growth analysis indices and vigour index of sandal seedlings are presented in Table 13.

Perusal of data indicated that at 30 DAT, the largest leaf area ratio (LAR) was shown by seedlings bioprimed at 100% for 8 days (12.12 $cm^2 g^{-1)}$ and the lowest was shown by seeds bioprimed at 75% for 3 days (0.93 $cm^2 g^{-1)}$. At 180 DAT also, same treatments 100% for 8 days (16.65 $cm^2 g^{-1}$) and 75% for 3 days (4.92 $cm^2 g^{-1}$) recorded the highest and lowest values, respectively. While, the largest leaf weight ratio (LWR) was shown by seedlings bioprimed at 75% % for 3 days (0.639) and the lowest was shown by seeds bioprimed at 50% for 2days (0.297) during first month of observation. At sixth month, seedlings bioprimed at 75% for 3 days (0.669) recorded the highest LWR and those at 50% for 2 days (0.383) recorded the lowest LWR. The root: shoot ratio was the highest in seedlings bioprimed at 25% for 1 day (0.3233) and the lowest was shown by those at 50% for 2 days (0.0476) at 30DAT. At 180 DAT also seeds bioprimed at 25% for 1day (0.598) recorded the highest ratio and the biopriming at 50% for 2 days and 3 days (0.192) recorded the lowest value. With regard to vigour index, highest VI is shown by seedlings bioprimed at 75% for 1 day (1083.1) and the lowest was shown by seeds bioprimed at 25 % for 4 days (21.5) at 30 DAT. At 180 DAT also, biopriming at 75% for 1 day (1488.7) recorded the highest VI of and that at 25% for 4 days (63.3) recorded the lowest VI.

Statistical analysis revealed the significant difference in LAR ($F=17.527$, $p < 0.01$), LWR ($F=37.932$, $p < 0.01$), root: shoot ratio ($F=40.094$, $p < 0.01$) and VI ($F=79.650$, $p < 0.01$) at 90 DAT due to interaction between bioinoculant concentration and duration. The interaction effect was significant at 180 DAT also in LAR ($F=16.596$, $p < 0.01$), LWR ($F=32.682$, $p < 0.01$), in root: shoot ratio ($F=9.364$, $p < 0.01$) and VI ($F=110.282$, $p < 0.01$).

Table 13 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Pseudomonas fluorescens		Leaf Area Ratio ($cm^2 g^{-1}$)		Leaf Weight Ratio		Root : Shoot ratio		Vigor index	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	3.30^{ab}	6.21^{ab}	0.434^{bc}	0.516^{bc}	0.323^{h}	0.598^{d}	814.123^{h}	1212.9^{i}
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	12.08^{c}	18.06^{abcd}	0.528^{bcd}	0.544^{bc}	0.084^{bc}	0.282^{abcd}	21.5^{ab}	63.3^{ab}
	6	4.76^{ab}	4.85^{ab}	0.45^{bc}	0.557^{bc}	0.136^{cde}	0.298^{abcd}	81.2^{abcd}	190.4^{bcd}
	8	-	-	-	-	-	-	-	-
50%	1	2.02^{ab}	4.85^{ab}	0.444^{bc}	0.472^{b}	0.129^{cde}	0.289^{abcd}	1114.8^{i}	1489.2^{i}
	2	29.89^{d}	36.74^{e}	0.297^{b}	0.383^{b}	0.047^{ab}	0.192^{ab}	157.5^{cdef}	258.9^{cde}
	3	4.55^{ab}	6.33^{abcd}	0.626^{cd}	0.654^{bc}	0.097^{bcd}	0.192^{ab}	133.9^{bcdef}	313.3^{def}
	4	3.24^{ab}	6.45^{a}	0.514^{bcd}	0.547^{bc}	0.214^{fg}	0.484^{bcd}	120.7^{abcde}	198.7^{bcd}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
75%	1	6.27^{ab}	11.84^{abcd}	0.492	0.494^{bc}	0.106^{bcd}	0.312^{abcd}	1083.1^{i}	1488.7^{i}
	2	10.99^{abc}	12.95^{abcd}	0.50^{bcd}	0.554^{bc}	0.153^{cdef}	0.425^{bcd}	55.9^{abc}	150.1^{abc}
	3	0.93^{ab}	4.92^{ab}	0.639^{cd}	0.669^{bc}	0.095^{bcd}	0.220^{abc}	482.1^{g}	762.9^{h}
	4	8.26^{abc}	11.24^{de}	0.532^{bcd}	$0.6b^{c}$	0.187^{efg}	0.541^{cd}	110.5^{abcd}	188.5^{bcd}
	6	-	-	-	-	-	-	-	-
	8	3.57^{ab}	8.68^{abcd}	0.693^{d}	0.712^{c}	0.088^{bc}	0.202^{ab}	175.0^{cdef}	276.4^{cde}
100%	1	4.87^{ab}	7.63^{abc}	0.458^{bcd}	0.524^{bc}	0.237^{g}	0.465^{bcd}	199.0^{def}	370.6^{efg}
	2	6.07^{ab}	11.04^{cde}	0.609^{cd}	0.618^{bc}	0.156^{cdef}	0.428^{bcd}	250.8^{f}	453.6^{fg}
	3	5.45^{abc}	9.68^{ab}	0.533^{bcd}	0.570^{bc}	0.155^{cdef}	0.352^{bcd}	85.7^{abcd}	187.1^{bcd}
	4	-	-	-	-	-	-	-	-
	6	8.51^{abc}	10.12^{abcd}	0.514^{bcd}	0.522^{bc}	0.168^{defg}	0.390^{bcd}	104.2^{abcd}	275.8^{cde}
	8	12.12^{bc}	16.65^{bcde}	0.561^{cd}	0.584^{bc}	0.149^{cdef}	0.331^{abcd}	245.3^{ef}	471.5^{g}
SEM		2.06	2.45	0.0441	0.0498	0.0139	0.0619	23.4	28.3
Main effects									

Concentration								
25%	4.35^{A}	5.50^{A}	0.235^{A}	0.269^{A}	0.091^{AB}	0.196^{A}	153.9^{A}	244^{A}
50%	8.29^{B}	10.45^{A}	0.314^{B}	0.329^{A}	0.081^{A}	0.195^{A}	254.9^{B}	377^{C}
75%	5.00^{A}	9.94^{A}	0.476^{C}	0.495^{B}	0.105^{B}	0.283^{AB}	318.9^{C}	478^{D}
100%	6.87^{AB}	9.81^{A}	0.446^{C}	0.452^{B}	0.144^{C}	0.328^{B}	148.9^{A}	293^{B}
SEM	0.839	1.00	0.018	0.0249	0.00566	0.0253	9.57	11.5
Duration								
1	4.11^{AB}	7.63^{A}	0.457^{C}	0.476^{C}	0.199^{D}	0.416^{D}	802.7^{E}	1140^{D}
2	13.45^{C}	15.47^{B}	0.352^{B}	0.376^{AB}	0.089^{B}	0.265^{BC}	116.0^{C}	216^{B}
3	3.79^{A}	5.76^{A}	0.449^{C}	0.461^{C}	0.087^{AB}	0.191^{AB}	175.4^{D}	316^{C}
4	8.19^{B}	9.14^{A}	0.393^{BC}	0.398^{BC}	0.121^{C}	0.327^{CD}	63.2^{AB}	113^{A}
6	3.32^{A}	5.23^{A}	0.241^{A}	0.270^{A}	0.076^{AB}	0.172^{AB}	46.4^{A}	117^{A}
8	3.92^{AB}	6.33^{A}	0.314^{AB}	0.319^{AB}	0.059^{A}	0.133^{A}	105.1^{BC}	187^{B}
SEM	1.03	1.23	0.022	0.0249	0.00694	0.031	11.7	11.5
Values within the same column with similar superscripts are homogenous								

4.5.2. Biopriming with *Trichoderma viride*

4.5.2.1. Seedling Growth

Impact of biopriming with *T. viride* at different durations and concentrations on the shoot parameters of sandal seedlings are presented in Table 14. In general biopriming positively influenced the seedling growth measured in terms of shoot height, collar diameter, leaf number, leaf area, root length, number of lateral roots and total seedling length.

Interaction effect of concentration and duration was significant in seedling height ($F=63.354$, $p < 0.01$), collar diameter ($F=17.096$, $p < 0.01$), leaf number ($F=19.617$, $p < 0.01$) and leaf area ($F=2.682$, $p < 0.01$) at 30 DAT and the interaction effect was also significant at 180 DAT in seedling height ($F=122.585$, $p < 0.01$), collar diameter ($F=32.101$, $p < 0.01$), leaf number ($F=27.054$, $p < 0.01$) and leaf area ($F=5.874$, $p < 0.01$). The highest shoot height was shown by seedlings bioprimed at 25 % for 4 days (17.77 cm) and the lowest value was shown by those at 25% for 3 days (2.97cm) at 30 DAT. At 180 DAT also seedlings bioprimed at 25% for 4 days (25.2 cm) recorded the highest seedling height and the seeds bioprimed at 25% for 3 days (10.4 cm) recorded the least. For the first month of observation, the largest collar diameter is shown by seedlings bioprimed at 25 % for 4 day (2.95 mm) and lowest was in biopriming at 25% for 2 days (0.927 mm). At sixth month also biopriming at 25% for 4 days (4.08 mm) recorded the highest value and but biopriming at 25 % for 2 days (2.06 mm) recorded the least collar diameter. Seedlings bioprimed at 75% for 8 days (26.7) recorded the largest number of leaves and the lowest was in biopriming at 50 % for 6 days (10.7) at 30 DAT. At 180 DAT, seedlings bioprimed at 75% for 8 days (30.7) recorded the highest leaf number and the lowest was in biopriming at 50% for 6 days (14.7). Meanwhile, the largest leaf area was shown by seedlings bioprimed at 75% for 2 day (6.75 cm^2) and the lowest was in biopriming at 100% for 1days(1.7 cm^2) at 30 DAT. At 180 DAT, seeds bioprimed at 100% for 3 days (8.52cm^2) recorded the highest leaf area and the seeds bioprimed at 100 % for 1 days (2.73 cm^2) recorded the lowest value.

The variation in root parameters of the bioprimed seedlings are given in Table 15 .For the first month of observation, the largest root length was shown by seedlings bioprimed at 100 % for 2 days (14.2 cm) and the lowest was in biopriming at 100% for 6 day (0.567cm). Similarly, at sixth month, seeds bioprimed at 100% for 2 days (18.5cm) recorded the highest root length and the seeds bioprimed at 100% for 6 days (4.87cm) recorded the lowest root length. At 30 DAT, the maximum root number was exhibited by seedlings bioprimed at 100% for 3days (14.67) and the minimum on biopriming at 75 % for 2 days and 100% for 1 day (2.00). Similarly, seedlings bioprimed at 100% for 3 days (16.67) recorded the highest and those at75% for 2 days and 100% for 1 day (3.33) recorded the lowest root number. With regard to the total seed length at first month, the highest value was observed in seedlings bioprimed at 25% for 4 days (30.20 cm) and the lowest was on biopriming at 100 % for 6 days (6.90 cm). At sixth month also, the seedlings bioprimed at 25% for 4 days (41.9 cm) recorded the highest total seedling length and the seeds bioprimed at 100% for 6 days (18.6) recorded the lowest.

Statistical analysis indicated that the interaction effect of concentration and duration was significant in root length ($F=43.682$, $p < 0.01$), number of roots ($F=6.891$, $p < 0.01$) and total seedling length ($F=96.665$, $p < 0.01$) at 30 DAT and the interaction effect was also significant at 180 DAT in root length ($F=50.910$, $p < 0.01$), number of roots ($F=8.598$, $p < 0.01$) and total seedling length ($F=159.211$, $p < 0.01$)

Table 14 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Trichoderma viride		Shoot Height (cm)		Collar Girth (mm)		Number of Leaves		Leaf Area (cm^2)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	12.10^{i}	19.50^{i}	1.05^{bc}	2.18^{bc}	14.30^{bc}	18.30^{bc}	4.37^{ab}	5.46^{bc}
	2	8.33^{efg}	15.70^{efg}	0.93^{ab}	2.06^{b}	14.00^{bc}	18.00^{bc}	6.30^{b}	3.65^{abc}
	3	2.97^{b}	10.40^{b}	1.08^{bcd}	2.21^{bcd}	14.70^{bc}	18.70^{bc}	5.82^{ab}	4.47^{abc}
	4	17.77^{i}	25.20^{i}	2.95^{h}	4.08^{h}	18.70^{c}	22.70^{c}	3.15^{ab}	3.62^{abc}
	6	13.20^{i}	20.60^{i}	2.22^{efgh}	3.35^{efgh}	17.30^{bc}	21.30^{bc}	4.57^{ab}	2.83^{ab}
	8	-	-	-	-	-	-	-	-
50%	1	11.47^{hi}	18.90^{hi}	1.95^{cdefg}	3.08^{cdefg}	16.70^{bc}	20.70^{bc}	6.12^{ab}	7.72^{bc}
	2	11.43^{hi}	18.80^{hi}	1.01^{bc}	2.14^{bc}	14.30^{bc}	18.30^{bc}	4.49^{ab}	5.53^{abc}
	3	6.03^{cde}	13.40^{cde}	1.43^{bcdef}	2.56^{bcdef}	13.30^{bc}	17.30^{bc}	2.68^{ab}	2.95^{ab}
	4	5.90^{cde}	13.30^{cde}	1.42^{bcdef}	2.55^{bcdef}	14.00^{bc}	18.00^{bc}	3.50^{ab}	7.76^{bc}
	6	4.67^{bc}	12.10^{bc}	1.81^{bcdefg}	2.94^{bcdefg}	10.70^{b}	14.70^{b}	2.65^{ab}	5.85^{bc}
	8	9.30^{ghi}	16.70^{ghi}	2.51^{gh}	3.64^{gh}	16.00^{bc}	20.00^{bc}	1.86^{ab}	6.69^{bc}
75%	1	7.63^{defg}	15.00^{defg}	2.36^{fgh}	3.49^{fgh}	16.30^{bc}	20.30^{bc}	6.59^{b}	3.9^{abc}
	2	8.17^{efg}	15.60^{efg}	1.90^{cdefg}	3.03^{cdefg}	16.30^{bc}	20.30^{bc}	6.75^{b}	3.08^{ab}
	3	-	-	-	-	-	-	-	-
	4	14.43^{i}	21.80^{i}	1.71^{bcdefg}	2.84^{bcdefg}	14.70^{bc}	18.70^{bc}	6.31^{b}	7.79^{bc}
	6	8.97^{fgh}	16.40^{fgh}	2.02^{defgh}	3.15^{defgh}	$16.00b^{c}$	20.00^{bc}	6.47^{b}	5.17^{bc}
	8	8.40^{efg}	15.80^{efg}	1.82^{bcdefg}	2.95^{bcdefg}	26.70^{d}	30.70^{b}	2.28^{ab}	2.81^{ab}
100%	1	8.87^{fgh}	16.30^{fgh}	1.36^{bcde}	2.49^{bcde}	16.30^{bc}	20.30^{bc}	1.70^{ab}	2.73^{ab}
	2	4.93^{bcd}	12.30^{bcd}	1.52^{bcdef}	2.65^{bcdef}	10.70^{b}	14.70^{b}	6.51^{b}	$7.87^{b}c$
	3	9.53^{ghia}	16.90^{ghi}	1.58^{bcdefg}	2.71^{bcdefg}	16.70^{bc}	20.70^{bc}	4.60^{ab}	8.52^{c}
	4	9.20^{gh}	16.90^{gh}	1.48^{bcdef}	2.61^{bcdef}	18.70^{c}	22.70^{c}	5.44^{ab}	6.30^{bc}
	6	6.33^{cdef}	13.70^{cdef}	1.52^{bcdef}	2.65^{bcdef}	18.30^{c}	22.30^{c}	2.65^{ab}	6.34^{bc}
	8	5.30^{bcd}	12.70^{bcd}	1.23^{bcd}	2.36^{bcd}	16.30^{bc}	20.30^{bc}	1.83^{ab}	7.20^{bc}
SEM		0.517	0.517	0.176	0.176	1.4	1.4	1.14	0.946
Main effects									

Concentration								
25%	9.49^{B}	15.7^{B}	1.37^{A}	2.31^{A}	13.2^{A}	16.5^{A}	4.04^{A}	5.34^{A}
50%	8.56^{A}	16.0^{B}	1.69^{B}	2.82^{B}	14.2^{AB}	18.2^{AB}	3.55^{A}	5.75^{B}
75%	8.36^{A}	14.5^{A}	1.64^{AB}	2.58^{AB}	15^{AB}	18.3^{AB}	4.73^{A}	4.99^{A}
100%	7.79^{A}	15.2^{AB}	1.45^{AB}	2.58^{AB}	16.2^{B}	20.2^{B}	3.79^{A}	6.49^{B}
SEM	0.211	0.211	0.072	0.072	0.573	0.573	0.467	0.386
Duration								
1	10.02^{D}	17.4^{D}	1.68^{BC}	2.81^{CD}	15.9^{B}	19.9^{B}	4.7B^{C}	4.95^{AB}
2	8.22^{C}	15.6^{C}	1.34^{AB}	2.47^{BC}	13.8^{AB}	17.8^{B}	6.01^{C}	6.53^{AB}
3	4.63^{A}	10.2^{A}	1.02^{A}	1.87^{A}	11.2^{A}	14.2^{A}	3.27^{BC}	3.99^{A}
4	11.82^{E}	19.2^{E}	1.89^{C}	3.02^{D}	16.5^{B}	20.5^{B}	4.6^{BC}	6.37^{B}
6	8.29^{C}	15.7^{C}	1.89^{C}	3.02^{D}	15.6^{B}	19.6^{B}	4.08^{BC}	5.05^{AB}
8	5.75^{B}	11.3^{B}	1.39^{AB}	2.24^{AB}	14.8^{B}	17.8^{B}	1.49^{A}	4.17^{A}
SEM	0.259	0.259	0.0882	0.0882	0.702	0.702	0.572	0.473
Values within the same column with similar superscripts are homogenous								

Table 15 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the root growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Trichoderma viride		Root Length (cm)		Number of Lateral Roots		Total Seedling Length	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	13.80^{hi}	18.10^{hi}	2.00^{ab}	3.67^{ab}	25.90^{i}	37.60^{i}
	2	13.90^{i}	18.20^{i}	3.00^{abc}	5.00^{abc}	22.23^{i}	33.90^{i}
	3	8.66^{efg}	12.97^{efg}	2.33^{ab}	3.67^{ab}	11.63^{bcde}	23.30^{bcde}

	4	12.43^{ghi}	16.73^{ghia}	7.67^{bc}	9.67^{bc}	30.20^{i}	41.90^{i}
	6	12.93^{hi}	17.23^{hia}	5.00^{abc}	6.33^{abc}	26.13^{i}	37.80^{i}
	8	-	-	-	-	-	-
50%	1	10.83^{fghi}	15.13^{fghi}	4.00^{abc}	6.33^{abc}	22.30^{i}	34.00^{i}
	2	13.68^{hia}	17.97^{hi}	4.00^{abc}	6.00^{abc}	25.10^{i}	36.80^{i}
	3	4.60^{bcde}	8.90^{bcde}	5.67^{abc}	7.67^{bc}	10.63^{bcd}	22.30^{bcd}
	4	1.27^{abc}	5.57^{bc}	6.67^{bc}	8.67^{bc}	7.17^{b}	18.90^{b}
	6	4.07^{abcd}	8.37^{bcd}	2.33^{ab}	4.33^{abc}	8.73^{bc}	20.40^{bc}
	8	4.90^{cde}	9.20^{cde}	5.67^{abc}	7.67^{bc}	14.20^{defg}	25.90^{defg}
75%	1	2.50^{abc}	6.80^{bc}	2.33^{ab}	3.67^{ab}	10.13^{bcd}	21.80^{bcd}
	2	4.53^{bcde}	8.83^{bcde}	2.00^{ab}	3.33^{ab}	12.70^{cdef}	24.40^{cdef}
	3	-	-	-	-	-	-
	4	13.13^{hia}	17.43^{hi}	9.00^{cd}	11.00^{cd}	27.57^{i}	39.30^{i}
	6	10.70^{fghia}	15.00^{fghi}	3.67^{abc}	5.00^{abc}	19.67^{hi}	31.40^{hi}
	8	3.53^{abcd}	7.83^{bcd}	3.00^{abc}	5.00^{abc}	11.93^{cdef}	23.60^{cdef}
100%	1	7.40^{def}	11.70^{def}	2.00^{ab}	3.33^{ab}	16.27^{efgh}	28.00^{efgh}
	2	14.20^{i}	18.50^{i}	4.33^{abc}	6.33^{abc}	19.13^{hi}	30.80^{hi}
	3	12.73^{ghi}	17.03^{ghi}	14.67^{d}	16.67^{d}	22.27^{i}	34.00^{i}
	4	9.63^{fgh}	13.93^{fgh}	2.67^{abc}	3.33^{ab}	18.83^{ghi}	30.50^{ghi}
	6	0.57^{ab}	4.87^{b}	2.33^{ab}	3.67^{ab}	6.90^{b}	18.60^{b}
	8	11.20^{fghi}	15.50^{fghi}	4.00^{abc}	5.00^{abc}	16.50^{fgh}	28.20^{fgh}
SEM		0.777	0.777	1.21	1.28	0.871	0.871
Main effects							
Concentration							
25%		10.29^{B}	13.87^{C}	3.33^{A}	4.72^{A}	20.1^{C}	29.1^{C}
50%		6.56^{A}	10.86^{B}	4.72^{A}	6.78^{B}	15.4^{A}	26.4^{B}
75%		5.73^{A}	9.32^{A}	3.33^{A}	4.67^{A}	14.4^{A}	23.4^{A}
100%		9.29^{B}	13.59^{C}	5.00^{A}	6.39^{AB}	17.4^{B}	28.4^{C}
SEM		0.317	0.317	0.493	0.523	0.356	0.356
Duration							

1	8.63^{CD}	12.93^{BC}	2.58^{A}	4.25^{A}	18.6^{C}	30.4^{C}
2	11.57^{E}	15.88^{D}	3.33^{AB}	5.17^{AB}	19.8^{CD}	31.5^{CD}
3	6.50^{AB}	9.72^{A}	5.67^{BC}	7.00^{BC}	11.1^{A}	19.9^{A}
4	9.12^{D}	13.42^{C}	6.50^{C}	8.17^{C}	20.9^{D}	32.6^{D}
6	7.07^{BC}	11.37^{B}	3.33^{AB}	4.83^{AB}	15.4^{B}	27.1^{B}
8	4.91^{A}	8.13^{A}	3.17^{AB}	4.42^{AB}	10.7^{A}	19.4^{A}
SEM	0.3888	0.388	0.604	0.641	0.436	0.436
Values within the same column with similar superscripts are homogenous						

4.5.2.2. Biomass production

Data pertaining to the fresh biomass accumulation of seedlings subjected to biopriming with *T.viride* at different concentration and duration are presented in Table16. During initial observation the largest stem fresh weight was shown by seedlings bioprimed at 100% for 1 day (0.5767 g) and the lowest was on biopriming at 50% for 1 day (0.0967 g). The similar treatments recorded the highest fresh weight at 180 DAT i.e. seeds bioprimed at 100 % for 1 day (0.617 g) recorded the highest stem fresh weight and the seeds bioprimed at 50 % for1 day (0.1 g) recorded the lowest weight. Whereas, the largest leaf fresh weight was shown by seedlings bioprimed at 100% for 1day (2.52 g) and the lowest was in biopriming at 100% for 6 days (0.160 g) at 30 DAT. At 180 DAT, seedlings bioprimed at 100% for 1 day (2.593 g) recorded the highest leaf fresh weight and those at 100 % for 6 days (0.230 g) recorded the lowest value .The maximum root fresh weight at 30 DAT was shown by seedlings bioprimed at 100% for 1 day (0.7933 g) and the lowest was at 75% for 4 days (0.05 g). Similarly, biopriming at 100% for 1 day (0.823 g) recorded the highest root fresh weight (0.05 g) and the biopriming at 75 % for 4 days (0.08 g) recorded the lowest value. The highest total fresh weight at 30 DAT was shown by seedlings bioprimed at 100% for 1 day (3.903 g) and lowest was in those at 25% for 2 days (0.480 g). At 180 DAT seedlings bioprimed at 100% for 1 day (3.993 g) recorded the highest fresh weight and those at 25% for 2 days (0.570 g) recorded the least.

Analysis of variance revealed significant difference in fresh weight of stem ($F=4.409$, $p < 0.01$), leaf ($F=169.182$, $p < 0.01$) and root ($F=48.336$, $p < 0.01$) and total fresh weight ($F=124.954$, $p < 0.01$) due to interaction effect of concentration and duration at 30 DAT and the interaction was also significant at 180 days in in fresh weight of stem ($F=4.303$, $p < 0.01$), leaf ($F=172.490$, $p < 0.01$) and root ($F=54.897$, $p < 0.01$) and total fresh weight ($F=127.628$, $p< 0.01$).

Variation in dry weight biomass of the sandal seedlings bioprimed with *T viride* at different duration and concentration are presented in Table 17. At 30 DAT, the highest stem dry weight was shown by the seedlings bioprimed at 75% for 2days (0.1833 g) and the lowest stem dry weight was in those at 100% for 8days (0.06 g). Similarly, seedlings bioprimed at 50% for 4 days (0.2911 g) recorded the highest and those at 100% for 8 days (0.096 g) recorded the lowest value. Concerning the leaf dry weight, at 30 DAT the maximum leaf dry weight was shown by seedlings bioprimed at 100% for 1 day (1.310 g) and the lowest was on biopriming at 100% for 6 days (0.107 g). At 180 DAT also, seedlings bioprimed at 100% for 1 day (1.682 g) recorded the highest leaf dry weight and those bioprimed at 100% for 6 days (0.120 g) showed the lowest. For the first month of observation, the largest root dry weight was recorded by seedlings bioprimed at 25 % for 4 days (0.431 g) and the lowest was at 75% for 4 days (0.025 g). Subsequently, at sixth month, seedlings bioprimed at 25% for 4 days (0.44 g) recorded the highest root dry weight and biopriming at 75% for 4 days (0.05 g) recorded the lowest value. During the initial observation the largest dry weight biomass was recorded by seedlings bioprimed at 75% for 6 days (1.033 g) and the lowest was at 25% for 2 days (0.290 g). At sixth month, seedlings bioprimed at 75% for 6 days (1.153 g) recorded the highest dry weight and the seedlings bioprimed at 100% for 6 days (0.307 g) recorded the lowest value. Analysis of variance revealed significant difference in dry weight of stem ($F=4.452$, $p < 0.01$), leaf ($F=52.011$, $p < 0.01$), root ($F=48.336$, $p < 0.01$) and total dry weight ($F=122.393$, $p < 0.01$) due to interaction effect of concentration and duration at 30 DAT. The interaction was also significant at 180 days in

dry weight of stem ($F=2.116$, $p < 0.01$), leaf ($F=15.814$, $p < 0.01$) and root ($F=6.897$, $p < 0.01$) and total weight ($F=23.983$, $p< 0.01$).

Table 16 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Trichoderma viride		Fresh weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	0.390^{cdef}	0.460^{cdef}	0.2567^{abc}	0.267^{abc}	0.233^{defg}	0.263^{defg}	0.890^{cdefg}	0.980^{cdefg}
	2	0.243^{bcd}	0.313^{bcd}	0.1667^{ab}	0.177^{ab}	0.06^{abc}	0.090^{abc}	0.480^{b}	0.570^{b}
	3	0.363^{bcde}	0.433^{bcde}	0.1667^{ab}	0.170^{ab}	0.193^{bcdef}	0.223^{bcdef}	0.727^{bcde}	0.817^{bcde}
	4	0.837^{g}	0.907^{g}	0.21^{ab}	0.220^{ab}	0.863^{h}	0.893^{h}	1.920^{ic}	2.010^{i}
	6	0.493^{ef}	0.563^{ef}	0.16^{ab}	0.170^{ab}	0.167^{bcde}	0.197^{bcde}	0.830^{bcdef}	0.920^{bcdef}
	8	-	-	-	-	-	-	-	-
50%	1	0.373^{bcdef}	0.443^{bcdef}	0.097^{ab}	0.100^{ab}	0.100^{abcd}	1.130^{abcd}	0.573^{bcd}	0.663^{bcd}
	2	0.827^{g}	0.897^{g}	0.247^{abc}	0.257^{abc}	0.197^{bcdef}	0.227^{bcdef}	1.280^{ghia}	1.370^{ghi}
	3	0.47^{def}	0.540^{def}	0.170^{ab}	0.180^{ab}	0.333^{fg}	0.363^{fg}	0.983^{efg}	1.073^{efg}
	4	0.597^{f}	0.667^{f}	0.427^{bc}	0.437^{bc}	0.150^{abcde}	0.180^{bcde}	1.183^{fgh}	1.273^{fgh}
	6	0.330^{bcde}	0.4^{bcde}	0.113^{ab}	0.120^{ab}	0.217^{cdefg}	0.247^{cdefg}	0.667^{bcde}	0.757^{bcde}
	8	0.903^{g}	0.973^{g}	0.323^{abc}	0.333^{abc}	0.370^{g}	0.400^{g}	1.607^{iaibic}	1.697^{i}
75%	1	0.983^{g}	1.053^{g}	0.210^{ab}	0.220^{ab}	0.303^{efg}	0.333^{efg}	1.507^{hiaib}	1.597^{hi}
	2	0.210^{abc}	0.280^{bc}	0.387^{bc}	0.397^{bc}	0.120^{abcd}	0.150^{abcd}	0.727^{bcde}	0.817^{bcde}
	3	-	-	-	-	-	-	-	-
	4	0.260^{bcd}	0.330^{bcd}	0.190^{ab}	0.200^{ab}	0.050^{ab}	0.080^{ab}	0.510^{bc}	0.600^{bc}
	6	1.347^{h}	1.417^{h}	0.287^{abc}	0.297^{abc}	0.087^{abcd}	0.117^{abcd}	1.730^{ibic}	1.820^{i}
	8	0.490^{ef}	0.560^{ef}	0.250^{abc}	0.260^{abc}	0.187^{bcdef}	0.217^{bcdef}	0.937^{defg}	1.027^{defg}
100%	1	2.523^{i}	2.593^{i}	0.577^{c}	0.587^{c}	0.793^{h}	0.823^{h}	3.903^{id}	3.993^{i}
	2	0.547^{ef}	0.617^{ef}	0.270^{abc}	0.280^{abc}	0.120^{abcd}	0.150^{abcd}	0.947^{defg}	1.037^{defg}
	3	0.517^{ef}	0.587^{ef}	0.307^{abc}	0.317^{abc}	0.157^{abcde}	0.187^{bcde}	0.998^{efg}	1.08^{efg}
	4	0.493^{ef}	0.563^{ef}	0.190^{ab}	0.200^{ab}	0.343^{fg}	0.373^{fg}	1.037^{efg}	1.127^{efg}
	6	0.160^{ab}	0.230^{b}	0.163^{ab}	0.173^{ab}	0.127^{abcd}	0.157^{abcd}	0.460^{b}	0.550^{b}
	8	0.397^{cdef}	0.467^{cdef}	0.133^{ab}	0.143^{ab}	0.147^{abcde}	0.177^{bcde}	0.687^{bcde}	0.777^{bcde}
SEM		0.0419	0.0419	0.0653	0.0653	0.0655	0.0301	0.0735	0.0735

Main effects								
Concentration								
25%	0.388^{A}	0.446^{A}	0.160^{A}	0.167^{A}	0.253^{BC}	0.278^{BC}	0.808^{A}	0.883^{A}
50%	0.583^{B}	0.653^{B}	0.231^{AB}	0.238^{AB}	0.228^{B}	0.258^{B}	1.049^{B}	1.139^{B}
75%	0.548^{B}	0.607^{B}	0.221^{AB}	0.229^{AB}	0.124^{A}	0.149^{A}	0.902^{A}	0.977^{A}
100%	0.773^{C}	0.843^{C}	0.273^{B}	0.283^{B}	0.281^{C}	0.311^{C}	1.337^{C}	1.427^{C}
SEM	0.0171	0.0171	0.0266	0.0268	0.0123	0.0123	0.03	0.03
Duration								
1	1.067^{D}	1.137^{D}	0.285^{A}	0.293^{A}	0.357^{B}	0.388^{B}	1.718^{D}	1.808^{D}
2	0.457^{B}	0.527^{B}	0.268^{A}	0.278^{A}	0.124^{A}	0.154^{A}	0.858^{B}	0.948^{B}
3	0.338^{A}	0.390^{A}	0.161^{A}	0.167^{A}	0.171^{A}	0.193^{A}	0.675^{A}	0.743^{A}
4	0.547^{C}	0.617^{C}	0.254^{A}	0.264^{A}	0.352^{B}	0.382^{B}	1.163^{C}	1.252^{C}
6	0.583^{C}	0.652^{C}	0.183^{A}	0.190^{A}	0.149^{A}	0.179^{A}	0.922^{B}	1.012^{B}
8	0.448^{B}	0.5^{B}	0.177^{A}	0.184^{A}	0.176^{A}	0.198^{A}	0.807^{AB}	0.875^{AB}
SEM	0.0209	0.0209	0.0326	0.0328	0.0151	0.0151	0.0368	0.0368
Values within the same column with similar superscripts are homogenous								

Table 17 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Trichoderma viride		Dry weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
	1	0.223^{abcd}	0.260^{cdef}	0.117^{a}	0.178^{abc}	0.117^{defg}	0.137^{abc}	0.477^{bcd}	0.593^{cdefg}

25%	2	0.153^{abc}	0.162^{bcd}	0.083^{a}	0.118^{ab}	0.030^{abc}	0.053^{a}	0.290^{ab}	0.320^{b}
	3	0.173^{abc}	0.242^{bcde}	0.113^{a}	0.15^{ab}	0.097^{bcdef}	0.110^{abc}	0.433^{abcd}	0.484^{bcde}
	4	0.453^{bcd}	0.558^{g}	0.113^{a}	0.147^{ab}	0.432^{h}	0.441^{d}	0.957^{ef}	1.280^{i}
	6	0.263^{abcd}	0.329^{ef}	0.113^{a}	0.213^{ab}	0.083^{bcde}	0.097^{abc}	0.523^{bcde}	0.553^{bcdef}
	8	-	-	-	-	-	-	-	-
50%	1	0.197^{abc}	0.249^{bcdef}	0.063^{a}	0.067^{ab}	0.050^{abcd}	0.070^{ab}	0.330^{abc}	0.382^{bcd}
	2	0.433^{bcd}	0.551^{g}	0.107^{a}	0.171^{abc}	0.098^{bcdef}	0.107^{abc}	0.647^{bcdef}	0.853^{ghi}
	3	0.227^{abcd}	0.313^{def}	0.073^{a}	0.120^{ab}	0.167^{fg}	0.187^{abcd}	0.487^{bcd}	0.656^{efg}
	4	0.290^{abcd}	0.398^{f}	0.173^{a}	0.291^{bc}	0.075^{abcde}	0.093^{abc}	0.557^{bcde}	0.789^{fgh}
	6	0.187^{abc}	0.220^{bcde}	0.070^{a}	0.080^{ab}	0.108^{cdefg}	0.167^{ab}c	0.333^{abcd}	0.44^{bcde}
	8	0.490^{cd}	0.602^{g}	0.140^{a}	0.222^{abc}	0.185^{g}	0.187^{abcd}	0.817^{def}	1.071^{i}
75%	1	0.473^{bcd}	0.656^{g}	0.107^{a}	0.147^{ab}	0.152^{efg}	0.160^{abc}	0.740^{cdef}	1.004^{bcde}
	2	0.127^{abc}	0.140^{abc}	0.183a	0.264^{bc}	0.060^{abcd}	0.077^{ab}	0.387^{abcd}	0.484^{bcde}
	3	-	-	-	-	-	-	-	-
	4	0.193^{abc}	0.173^{bcd}	0.077^{a}	0.133^{ab}	0.025^{ab}	0.047^{a}	0.317^{abc}	0.340^{bc}
	6	0.590^{d}	0.898^{h}	0.167^{a}	0.198^{abc}	0.043^{abcd}	0.277^{bcd}	1.033^{f}	1.153^{i}
	8	0.223^{abcd}	0.328^{ef}	0.120^{a}	0.173^{abc}	0.093^{bcdef}	0.100^{abc}	0.443^{abcd}	0.624^{defg}
100%	1	1.310^{e}	1.682^{ia}	0.240^{a}	0.391^{c}	0.397^{h}	0.400^{cd}	1.850^{g}	2.602^{i}
	2	0.273^{abcd}	0.364^{ef}	0.130^{a}	0.187^{abc}	0.06^{abcd}	0.073^{ab}	0.477^{bcd}	0.631^{defg}
	3	0.280^{abcd}	0.344^{ef}	0.167^{a}	0.211^{abc}	0.078^{abcde}	0.100^{abc}	0.547^{bcde}	0.660^{efg}
	4	0.230^{abcd}	0.329^{ef}	0.090^{a}	0.133^{ab}	0.172^{fg}	0.197^{abc}	0.477^{bcd}	0.691^{efg}
	6	0.107^{ab}	0.120^{ab}	0.090^{a}	0.116^{ab}	0.063^{abcd}	0.080^{ab}	0.290^{ab}	0.307^{b}
	8	0.217^{abc}	0.264^{cdef}	0.060^{a}	0.096^{ab}	0.073^{abcde}	0.077^{ab}	0.353^{abc}	0.458^{bcde}
SEM		0.0678	0.0678	0.046	0.046	0.0279	0.0388	0.049	0.0815
Main effects									
Concentration									
25%		0.211^{A}	0.259^{A}	0.113^{A}	0.147^{A}	0.126^{BC}	0.131^{A}	0.455^{A}	0.539^{A}
50%		0.304^{AB}	0.389^{B}	0.108^{A}	0.194^{AB}	0.114^{B}	0.135^{A}	0.547^{AB}	0.699^{B}
75%		0.268^{A}	0.366^{B}	0.109^{A}	0.188^{AB}	0.062^{A}	0.110^{A}	0.487^{A}	0.601^{A}
100%		0.405^{B}	0.515^{C}	0.129^{A}	0.225^{B}	0.141^{C}	0.151^{A}	0.666^{B}	0.891^{C}

SEM	0.0114	0.0277	0.0178	0.0188	0.00615	0.0159	0.02	0.033
Duration								
1	0.551^{B}	0.712^{D}	0.1317^{A}	0.196^{A}	0.178^{B}	0.197^{B}	0.849^{C}	1.146^{D}
2	0.247^{A}	0.304^{B}	0.1258^{A}	0.185^{A}	0.062^{A}	0.078^{A}	0.450^{AB}	0.572^{B}
3	0.170^{A}	0.225^{A}	0.0975^{A}	0.111^{A}	0.085^{A}	0.099^{AB}	0.367^{A}	0.450^{A}
4	0.292^{A}	0.364^{C}	0.1133^{A}	0.176^{A}	0.176^{B}	0.192^{B}	0.577^{B}	0.775^{C}
6	0.290^{A}	0.388^{C}	0.114^{A}	0.127^{A}	0.075^{A}	0.155^{AB}	0.585^{B}	0.614^{B}
8	0.233^{A}	0.298^{B}	0.080^{A}	0.123^{A}	0.088^{A}	0.091^{AB}	0.403^{A}	0.538^{AB}
SEM	0.014	0.0339	0.0218	0.0233	0.00753	0.0194	0.0245	0.0408
Values within the same column with similar superscripts are homogenous								

4.5.2.3. Plant Growth analysis indices and vigour index

The effect biopriming with *T. viride* at different duration and concentration on the on leaf area ratio, leaf weight ratio and root: shoot ratio and vigour index of sandal seedlings is depicted in Table 18. With regard to leaf area ratio, for the first month of observation the largest LAR is shown by seedlings bioprimed at 75% for 4 days (18.789 $cm^2 g^{-1)}$ and lowest was in seedlings bioprimed at 100% for 1day (0.658 $cm^2 g^{-1)}$ ·At sixth month also, seedlings bioprimed at 75% for 4 days (24.56 $cm^2 g^{-1)}$ recorded the highest LAR and the seeds bioprimed at100% for 1 day (1.48 $cm^2 g^{-1)}$ recorded the lowest LAR. At 30 DAT, the largest LWR was shown by seedlings bioprimed at 75 % for 1day (0.655) and the lowest was at 75% for 2 days (0.365). The seedlings bioprimed at 75% for 1 day (0.692) recorded the highest LWR and those 75% for 2 days (0.386) recorded the lowest value at 180 DAT. The largest root: shoot ratio at 30 DAT was shown by seedlings bioprimed at 25% for 3 days (0.1608) and the lowest was in those at 75 % for 6 days (0.0322). Seeds bioprimed at 25% for 1 day (0.424) recorded the highest root: shoot ratio and the seeds bioprimed at 75 % for 4 days (0.172) recorded the lowest root: shoot ratio at 180 DAT. The largest VI at 30 DAT was shown by seedlings bioprimed at 100% for 1 day (1193.5) and the lowest was on biopriming at 25% for 3 days (69.8). At sixth month, seedlings bioprimed at 100% for 1 day (2052) recorded the highest VI and the seeds bioprimed at 25% for 3 days (140) recorded the lowest VI. Statistical analysis revealed significant difference in leaf area ratio ($F=6.939$, $p < 0.01$), leaf weight ratio, ($F=14.572$, $p < 0.01$) root: shoot ratio ($F=11.118$, $p < 0.01$) and vigour index ($F=92.702$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT. The interaction was also significant at 180 days in leaf area ratio ($F=10.111$, $p < 0.01$), leaf weight ratio ($F=5.823$, $p < 0.01$) root: shoot ratio ($F=5.425$, $p < 0.01$) and vigour index ($F=125.417$, $p < 0.01$).

Table 18 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Trichoderma viride		Leaf Area Ratio (cm2g-1)		Leaf Weight Ratio		Root : Shoot ratio		Vigor index	
Concentration	Duration (days)	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT
25%	1	7.749^{bcde}	11.48^{bcde}	0.436^{bcd}	0.464^{b}	0.152^{defgh}	0.424^{bcde}	897.3^{i}	1303^{if}
	2	13.31^{e}	23.11^{bcde}	0.527^{bcd}	0.531^{b}	0.072^{bcde}	0.231^{bcd}	370.3^{fg}	565^{i}
	3	11.34^{bcde}	12.07^{bcde}	0.502^{bcd}	0.516^{b}	0.161^{efgh}	0.407^{bcde}	69.8^{b}	140^{b}
	4	2.449^{bc}	3.78^{bc}	0.435^{bcd}	0.468^{b}	0.303^{i}	0.719^{e}	383.12^{g}	531^{i}
	6	5.97^{bcde}	8.075^{bc}	0.492^{cde}	0.594	0.125^{cdefg}	0.251^{bcd}	261.6^{def}	379^{fghi}
	8	-	-	-	-	-	-	-	-
50%	1	16.80^{cde}	23.17^{e}	0.595^{de}	0.651^{a}	0.110^{bcde}	0.269^{abcd}	535.2^{h}	816^{i}
	2	5.36^{abcd}	6.39^{abc}	0.646^{de}	0.669^{b}	0.095^{bcde}	0.199^{abcd}	636.7^{h}	933^{i}
	3	4.136^{abc}	6^{abc}	0.476^{bcd}	0.540^{b}	0.214^{hi}	0.630^{de}	205.3^{cde}	431^{ghi}
	4	4.371^{abcd}	7.53^{bcde}	0.518^{bcd}	0.531^{b}	0.0698^{abcd}	0.202^{abcd}	81.4^{ab}	214^{bc}
	6	5.921^{abcde}	13.17^{abcde}	0.498^{bcd}	0.512^{b}	0.213^{gh}	0.620^{cde}	92^{ab}	217^{bcd}
	8	1.783^{ab}	8.36^{abcd}	0.563^{bcde}	0.592^{b}	0.144^{cdefgh}	0.313^{abcde}	133.2^{bc}	242^{bcdef}
75%	1	6.742^{abcde}	7.39^{abc}	0.655^{de}	0.692^{b}	0.130^{cdefgh}	0.275^{abcd}	364.8^{fg}	786^{i}
	2	8.570^{bcde}	16.201^{abcd}	0.365^{bc}	0.386^{b}	0.085^{abcde}	0.235^{abcd}	118.12^{bc}	227^{bcde}
	3	-	-	-	-	-	-	-	-
	4	18.789^{de}	24.56^{e}	0.532^{bcd}	0.616^{b}	0.055^{abc}	0.172^{ab}	220.5^{cde}	314^{cdefg}
	6	5.626^{abcd}	6.73^{abc}	0.484^{e}	0.577^{b}	0.032^{ab}	0.470^{bcde}	222.7^{cde}	355^{defgh}
	8	3.773^{abc}	6.40^{abc}	0.522^{bcd}	0.599^{b}	0.119^{bcdef}	0.305^{abcde}	182.7^{bcd}	362^{efgh}
100%	1	0.658^{a}	1.48^{ab}	0.646^{de}	0.707^{b}	0.133^{cdefgh}	0.195^{abcd}	1193.5^{ib}	2052^{ig}
	2	10.242^{abcde}	16.68^{cde}	0.578^{bcde}	0.593^{b}	0.073^{abcde}	0.185^{abc}	371.12^{fg}	597^{i}
	3	6.918^{abcde}	15.6^{cde}	0.522^{bcd}	0.542^{b}	0.091^{bcde}	0.227^{abcd}	578.9^{h}	883^{i}
	4	7.790^{abcde}	13.06^{abcde}	0.481^{bcd}	0.499^{b}	0.207^{fgh}	0.497^{bcde}	313.9^{efg}	509^{i}
	6	8.542^{abcde}	13.10^{e}	0.351^{b}	0.408^{b}	0.154^{defgh}	0.426^{abcde}	170^{bcd}	459^{hi}
	8	3.986^{abc}	5.887^{de}	0.578^{bcde}	0.612^{b}	0.133^{cdefgh}	0.286^{abcde}	539.5^{h}	922^{i}
SEM		2.67	2.46	0.0444	0.0674	0.0163	0.0806	20.7	25.7

Main effects								
Concentration								
25%	8.35^{A}	9.77^{A}	0.395^{A}	0.416^{A}	0.1355^{B}	0.339^{AB}	330^{C}	486^{B}
50%	6.40^{A}	11.74^{BC}	0.545^{B}	0.559^{C}	0.1410^{B}	0.372^{B}	281^{B}	476^{B}
75%	8.52^{A}	9.44^{AB}	0.438^{A}	0.475^{AB}	0.0702^{A}	0.243^{A}	185 ^{A}	341^{A}
100%	6.36^{A}	11.04^{C}	0.510^{B}	0.526^{BC}	0.1319^{B}	0.303^{AB}	528^{D}	904^{C}
SEM	1.09	1.00	0.0181	0.0275	0.00666	0.0329	8.47	10.5
Duration								
1	7.99^{ABC}	10.38^{AB}	0.597^{D}	0.602^{C}	0.1313^{BC}	0.291^{AB}	748^{D}	1265^{C}
2	13.07^{C}	14.99^{AB}	0.529^{CD}	0.540^{BC}	0.0816	0.213^{A}	374^{C}	607^{B}
3	5.60^{AB}	8.42^{A}	0.375^{A}	0.397^{A}	0.1165^{B}	0.316^{AB}	214^{AB}	389^{A}
4	8.35^{BC}	13.94^{B}	0.492^{BC}	0.526^{BC}	0.1588^{C}	0.397^{B}	250^{B}	418^{A}
6	7.04^{AB}	11.99^{AB}	0.555^{CD}	0.592^{AB}	0.1310^{BC}	0.442^{B}	187^{A}	378^{A}
8	2.39^{A}	6.77^{A}	0.416^{AB}	0.452^{AB}	0.0987^{AB}	0.226^{A}	214^{AB}	382^{A}
SEM	1.34	1.23	0.0222	0.0337	0.00815	0.0403	10.4	12.9
Values within the same column with similar superscripts are homogenous								

4.5.3. Biopriming with PGPR II

4.5.3.1. Seedling Growth

Impact of biopriming with PGPRII at different duration and concentration on the shoot characteristics of sandal seedlings are presented in Table 19. The tallest seedlings were recorded in biopriming at 100% for 2 days (19.77 cm) and shortest was at 75 % for 2 days (4.33 cm) at 30 DAT. At 180 DAT also the seeds bioprimed at 100% for 2 days (27.2 cm) recorded the highest seedling height and those at 75 % for 2 days (11.7 cm) recorded the lowest seedling height. The largest collar diameter was shown by seedlings bioprimed at 100% for 6 days (2.047 mm) and the lowest was on biopriming at 50% for 6 days (0.717 mm). At 180 DAT also, seedlings bioprimed at 100% for 6 days (3.18 mm) recorded the highest collar diameter and the seeds bioprimed at 50 % for 6 days (1.85 mm) recorded the lowest values. For the first month of observation the largest leaf number was recorded by seedlings bioprimed at 75% for 4 days (20) and the lowest was on biopriming at 50% for 6 days (10.3). At sixth month, seeds bioprimed at for 75% for 4 days (24) and the lowest was shown by seeds bioprimed at 50% for 6 days (14.3).With regard to leaf area, at 30 DAT the largest value was shown by seedlings bioprimed at 75% for 3days (7.09 cm^2) and the lowest was at 25 % for 6days.(1.60 cm^2). At 180 DAT, seedlings bioprimed at 100% for 4 days (7.72 cm^2) recorded the highest leaf area and the seeds bioprimed at 25 % for 6 days (4.40 cm^2) recorded the lowest value. The difference in shoot height ($F=15.621$, $p < 0.01$), collar diameter ($F=18.274$, $p < 0.01$), leaf number ($F=34.403$, $p < 0.01$) and leaf area ($F=2.397$, $p < 0.01$) was significant due to interaction effect of concentration and duration of bioinoculant at 30 DAT. The interaction was also significant at 180 days in seedling height ($F=27.056$, $p < 0.01$), collar diameter ($F=41.756$, $p < 0.01$), leaf number ($F=49.134$, $p < 0.01$) and leaf area ($F=5.874$, $p < 0.01$).

The impact of biopriming with PGPR II at different durations and concentrations on the root characteristics of sandal seedlings are presented in Table 20. At first month of observation, the largest root length was observed in seedlings bioprimed at 50 % for 4 days (12.67 cm) and the lowest was in seedlings bioprimed at 50 % for 8 days (0.60 cm). At sixth month, seedlings bioprimed at 50 % for 4 days (16.97 cm) recorded the highest root length and those at 50 % for 8 days (4.23 cm) recorded the lowest. At 30 DAT, the largest root number was shown by seedlings bioprimed at 100 % for 3 days (10.67) and the lowest was on biopriming at 75% for 2 days (2.33). At 180 DAT, seeds bioprimed at 100 % for 3days (12.67) recorded the highest root number and the seedlings bioprimed at 75 % for 2 days, 100 % for 2 days and 25 % for 1 day (3.67) recorded the lowest root number.

During the first month of observation the largest total seedling length was shown by seedlings bioprimed at 100% for 3 days (35.43 cm) and the lowest was on biopriming at 100 % for 8 days (6.53 cm) At sixth month, seeds bioprimed at 100 % for 3 days (47.1 cm) recorded the highest total seedling length and the lowest was for seeds bioprimed at 50 % for 8 days (17.9 cm). The difference in root length ($F=40.596$, $p < 0.01$), number of roots ($F=4.449$, $p < 0.01$) and total seedling length ($F=49.685$, $p < 0.01$) was significant due to interaction effect of concentration and duration of bioinoculant at 30 DAT. The interaction was also significant at 180 days in root length ($F=60.503$, $p < 0.01$), number of roots ($F=60.898$, $p < 0.01$) and total seedling length ($F=2.397$, $p < 0.01$).

Table 19 Effect of biopriming with different concentrations of PGPR II at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

PGPR 2		Shoot Height (cm)		Collar Girth (mm)		Number of Leaves		Leaf Area (cm^2)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	14.40^{defg}	21.80^{defg}	0.85^{bc}	1.98^{bc}	17.3^{de}	21.30^{de}	5.57^{a}	6.09^{ab}
	2	-	-	-	-	-	-	-	-
	3	11.57^{cdef}	19.00^{cdef}	1.45^{bcde}	2.58^{bcde}	16.70^{cde}	20.70^{cde}	5.18^{a}	5.65^{abc}
	4	5.00^{abc}	12.40^{bc}	1.62^{cde}	2.75^{cde}	14.00^{bcd}	18.00^{bcd}	6.04^{a}	6.56^{bcd}
	6	4.60^{abc}	12.00^{bc}	1.48^{bcde}	2.61^{bcde}	19.70^{de}	23.70^{de}	1.60^{a}	4.40^{abc}
	8	-	-	-	-	-	-	-	-
50%	1	8.63^{bcdef}	16.00^{bcdef}	1.78^{de}	2.91^{de}	18.30^{de}	22.30^{de}	5.99^{a}	10.76^{d}
	2	7.50^{bcde}	14.90^{bcde}	1.55^{cde}	2.68^{cde}	15.00^{bcde}	19.00^{bcde}	4.48^{a}	7.44^{bcd}
	3	-	-	-	-	-	-	-	-
	4	14.60^{defg}	22.00^{defg}	0.85^{bc}	1.98^{bc}	11.00^{bc}	15.00^{bc}	4.42^{a}	7.75^{bcd}
	6	9.87^{bcdef}	17.30^{bcdef}	0.72^{ab}	1.85^{b}	10.30^{b}	14.30^{b}	3.34^{a}	8.58^{cd}
	8	6.23^{abc}	13.60^{bc}	1.98^{e}	3.11^{e}	17.00^{de}	19.30^{bcde}	5.77^{a}	8.55^{abc}
75%	1	14.93^{efg}	22.30^{efg}	1.08^{bcd}	2.21^{bcd}	10.30^{b}	14.30^{b}	2.97^{a}	6.44^{bcd}
	2	4.33^{abc}	11.70^{bc}	1.64^{cde}	2.77^{cde}	15.30^{bcde}	19.30^{bcde}	5.93^{a}	6.61^{bcd}
	3	7.33^{abcd}	14.70^{bcd}	1.11^{bcd}	2.24^{bcd}	17.70^{de}	21.70^{de}	7.09^{a}	7.47^{bcd}
	4	13.97^{defg}	21.40^{defg}	1.08^{bcd}	2.21^{bcd}	20.00^{e}	24.00^{e}	7.03^{a}	7.46^{bcd}
	6	9.77^{bcdef}	17.20^{bcdef}	1.98^{e}	3.11^{e}	17.70^{de}	21.70^{de}	4.53^{a}	5.46^{abcd}
	8	10.83^{bcdef}	18.20^{bcdef}	1.06^{bcd}	2.19^{bcd}	16.30^{cde}	20.30^{cde}	4.47^{a}	6.46^{abc}
100%	1	8.87^{bcdef}	16.30^{bcdef}	1.54^{cde}	2.67^{cde}	16.00^{bcde}	20.00^{bcde}	3.98^{a}	5.92^{abc}
	2	19.77^{g}	27.20^{g}	1.49^{bcde}	2.62^{bcde}	19.70^{de}	23.70^{de}	3.31^{a}	5.83^{abc}
	3	15.70^{fg}	23.10^{fg}	1.68^{de}	2.81^{de}	16.70^{cde}	20.70^{cde}	4.73^{a}	7.56^{bcd}
	4	7.57^{bcde}	15.00^{bcde}	1.28^{bcde}	2.41^{bcde}	18.30^{de}	22.30^{de}	5.44^{a}	7.72^{bcd}
	6	11.10^{bcdef}	18.50^{bcdef}	2.05^{e}	3.18^{e}	16.30^{cde}	20.30^{cde}	6.00^{a}	7.53^{abc}
	8	3.87^{ab}	11.30^{b}	1.03^{bcd}	2.16^{bcd}	17.30^{de}	21.30^{de}	3.59^{a}	3.95^{abc}
SEM		1.37	1.37	0.151	0.151	1.148	1.1	1.4	1.91
Main effects									

Concentration								
25%	5.92^{A}	10.9^{A}	0.90^{A}	1.65^{A}	11.3^{A}	13^{A}	3.07^{A}	3.95^{A}
50%	7.80^{A}	14.0^{B}	1.15^{B}	2.09^{B}	11.9^{A}	15.3^{A}	4.00^{AB}	6.35^{B}
75%	10.19^{B}	17.6^{C}	1.33^{BC}	2.46^{C}	16.2^{B}	20.2^{B}	5.73^{B}	5.82^{B}
100%	11.14^{B}	18.5^{C}	1.51^{C}	2.64^{C}	17.4^{B}	21.4^{B}	4.84^{AB}	4.90^{B}
SEM	0.56	0.56	0.0616	0.0616	0.449	0.449	0.453	0.573
Duration								
1	11.7^{C}	19.1^{C}	1.31^{AB}	2.44^{BC}	15.5^{B}	19.5^{B}	5.13^{A}	5.73^{BC}
2	7.9^{AB}	13.4^{AB}	1.17^{A}	2.02^{A}	12.5^{A}	15.5^{A}	3.43^{A}	4.22^{AB}
3	8.65^{B}	14.2^{B}	1.06^{A}	1.91^{A}	12.8^{A}	15.8^{A}	4.34^{A}	4.83^{ABC}
4	10.28^{BC}	17.7^{C}	1.21^{A}	2.34^{B}	15.8^{B}	19.8^{B}	5.73^{A}	6.87^{C}
6	8.83^{BC}	16.2^{BC}	1.56^{B}	2.69^{C}	16.0^{B}	20.0^{B}	3.87^{A}	5.04^{ABC}
8	5.23^{A}	10.8^{A}	1.02^{A}	1.86^{A}	12.7^{A}	15.7^{A}	3.96^{A}	4.15^{A}
SEM	0.685253	0.685	0.0754	0.0754	0.5548	0.55	0.702	0.777
Values within the same column with similar superscripts are homogenous								

Table 20 Effect of biopriming with different concentrations of PGPR II at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

PGPR 2		Root Length (cm)		Number of Lateral Roots		Total Seedling Length	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
	1	4.97^{cdefg}	9.27^{cdef}	3.33^{ab}	3.67^{ab}	19.37^{efgh}	31.10^{efg}
	2	-	-	-	-	-	-

25%	3	11.5^{i}	15.83^{i}	5.33^{abc}	6.33^{abc}	23.10^{fghi}	34.80^{efgh}
	4	3.60^{abcde}	7.90^{bcd}	2.67^{ab}	4.67^{ab}	8.60^{bc}	20.30^{bc}
	6	4.80^{cdefg}	9.10^{cdef}	3.00^{ab}	5.00^{ab}	9.40^{bc}	21.10^{bc}
	8	-	-	-	-	-	-
50%	1	13.33^{i}	17.63^{i}	2.67^{ab}	4.67^{ab}	21.97^{fghi}	33.70^{efgh}
	2	10.33^{i}	14.63^{hi}	6.00^{bc}	8.00^{bc}	17.83^{defg}	29.50^{def}
	3	-	-	-	-	-	-
	4	12.67^{i}	16.97^{i}	6.00^{bc}	8.00^{bc}	27.27^{hi}	39.00^{ghi}
	6	5.33^{defgh}	9.63^{cdefg}	4.67^{ab}	5.67^{ab}	15.20^{cdef}	26.90^{cde}
	8	0.60^{ab}	4.23^{b}	3.00^{ab}	3.67^{ab}	6.83^{ab}	17.90^{b}
75%	1	11.10^{i}	15.40^{i}	4.67^{ab}	9.33^{bc}	26.03^{ghi}	37.70^{fgh}
	2	5.73^{defgh}	10.03^{cdefg}	2.33^{ab}	3.67^{ab}	10.07^{bcd}	21.80^{bcd}
	3	8.47^{ghi}	12.77^{fghi}	7.33^{bc}	9.33^{bc}	15.80^{cdef}	27.50^{cde}
	4	12.17^{i}	16.47^{i}	4.67^{ab}	4.97^{ab}	26.13^{hi}	37.80^{gh}
	6	6.73^{efghi}	11.03^{defgh}	4.33^{ab}	4.77^{ab}	16.50^{cdef}	28.20^{cde}
	8	4.37^{bcdef}	8.67^{cde}	3.00^{ab}	5.00^{ab}	15.20^{cdef}	26.90^{cde}
100%	1	11.20^{i}	15.50^{i}	3.00^{ab}	5.00^{ab}	20.07^{efgh}	31.80^{efg}
	2	9.13^{hi}	13.43^{ghi}	2.67^{ab}	3.67^{ab}	28.90^{i}	40.60^{hi}
	3	19.73^{if}	24.03^{ie}	10.67^{c}	12.67^{c}	35.43^{ib}	47.10^{i}
	4	8.17^{fghi}	12.47^{efghi}	6.00^{bc}	7.33^{ab}	15.73^{cdef}	27.40^{cde}
	6	1.10^{abc}	4.30^{b}	4.00^{ab}	6.00^{ab}	12.20^{bcde}	22.80^{bcd}
	8	2.67^{abcd}	6.97^{bc}	2.67^{ab}	3.67^{ab}	6.53^{ab}	18.20^{b}
SEM		0.717	0.717	1.06	1.18	1.51	1.51
Main effects							
Concentration							
25%		4.15^{A}	7.02^{A}	2.39^{A}	3.28^{A}	10.1^{A}	17.9^{A}
50%		7.04^{B}	10.52^{B}	3.72^{AB}	5.00^{AB}	14.8^{B}	24.5^{B}
75%		8.09^{BC}	12.39^{C}	4.39^{B}	5.44^{B}	18.3^{C}	30.0^{C}
100%		8.67^{C}	12.78^{C}	4.83^{B}	5.89^{B}	19.8^{C}	31.3^{C}
SEM		0.29	0.359	0.484	0.484	0.616	0.617
Duration							

1	10.15^{D}	14.45^{C}	3.42^{AB}	4.75^{AB}	21.86^{D}	33.6^{D}
2	6.30^{C}	9.53^{B}	2.75^{AB}	3.83^{A}	14.2^{B}	23^{B}
3	9.93^{B}	13.16^{C}	5.83^{C}	7.08^{B}	18.58^{C}	27.4^{C}
4	9.15^{D}	13.45^{C}	4.83^{BC}	5.42^{AB}	19.43^{CD}	31.1^{D}
6	4.492^{B}	8.52^{B}	4.00^{ABC}	5.25^{AB}	13.32^{B}	24.8^{BC}
8	1.90^{A}	4.97^{A}	2.17^{A}	3.08^{A}	7.14^{A}	15.8^{A}
SEM	0.36	0.359	0.531	0.592	0.754	0.755
Values within the same column with similar superscripts are homogenous						

4.5.3.2. Biomass production

Table 21 depicts the variation in fresh weight of the sandal seedlings bioprimed with PGPR II at different duration and concentration. Stem fresh weight was the highest in the seedlings bioprimed at 50 % for 8 days (0.6367 g) and the lowest was at 100 % for 8 days (0.0967 g) at 30 DAT. At 180 DAT seedlings bioprimed at 50% for 8 days (0.647 g) recorded the highest stem fresh weight and the seeds bioprimed at 100% for 8 days (0.107 g) recorded the lowest value. For the first month of observation, the largest leaf fresh weight was shown by seedlings bioprimed at 75% for 1 day (1.290 g) and the lowest was at 100% for 8 days (0.243 g). At sixth month, seeds bioprimed at 75%for 1 day (1.360 g) recorded the highest fresh weight and those at 100 % for 8 days (0.313 g) recorded the lowest value. The root fresh weight at 30 DAT was the highest in seedlings bioprimed at 75% for 1day (0.780 g) and the lowest on biopriming at 75% for 6 days (0.137 g). At 180 DAT, seedlings bioprimed at 75% for 1 day (0.810 g) recorded the highest fresh weight (root) and those at 75 % for 6 days (0.167 g) recorded the lowest. For the first month of observation the largest total fresh weight was observed in seedlings bioprimed at 75% for 1 day (2.40 g) and the lowest was on biopriming at 100% for 8 days (0.517g). At sixth month, seedlings bioprimed at 75% for 1 day (2.49 g) recorded the highest total fresh weight and those at 100 % for 8 days (0.607 g) recorded the lowest value. .

Statistical analysis revealed significant difference in fresh weight of stem($F=4.542$, $p < 0.01$), leaf ($F=34.600$, $p < 0.01$) and root ($F=14.497$, $p < 0.01$) and total fresh weight ($F=45.033$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT and the interaction was also significant at 180 days in fresh weight of stem ($F=60.898$, $p < 0.01$), leaf ($F=42.824$, $p < 0.01$) and root ($F=15.189$, $p < 0.01$) and total fresh weight($F=48.736$, $p< 0.01$).

The effect of biopriming with PGPR II on dry biomass production of the seedlings is given in the Table 22. The highest stem dry weight was shown by seedlings bioprimed at 50% for 8 days (0.270 g) and the lowest was at 50% for 4 days (0.07 g) at 30 DAT. At 180 DAT, seedlings bioprimed at 50% for 8 days (0.4311 g) recorded the highest stem dry weight and the seedlings bioprimed at 50% for 4 days (0.0933 g) recorded the lowest. The seedlings with largest leaf dry weight was observed in biopriming at 75 % for 1day and 75% for 3 days (0.720 g) and the lowest was in those at 50% for4 days (0.197 g). At 180 DAT, seedlings bioprimed at 75% for 1 day (0.860 g) recorded the highest dry weight (leaf) and on biopriming at 50 % for 8 days (0.384 g) recorded the lowest. The largest root weight was recorded by seedlings bioprimed at 75% for 1 day (0.390 g) and the lowest was at 100% for 8 days (0.083 g) at 30 DAT. At 180 DAT, seeds bioprimed at 75% for 1 day (0.663 g) recorded the highest root dry weight and at 100 % for 8 days (0.0933 g) recorded the lowest value. When the total biomass production was compared the largest dry weight was in biopriming at 75% for 1 day (1.53 g) and the lowest dry weight was at 50% for 1 day (0.447 g) at 30 DAT. At 180 DAT, seeds bioprimed at 75 % for 1 day (1.600 g) recorded the highest dry weight and the seedlings bioprimed at 100 % for 8 days (0.344 g) recorded the lowest dry weight.

Statistical analysis revealed significant difference in dry weight of stem ($F=4.499$, $p < 0.01$), leaf ($F=10.215$, $p < 0.01$) , root ($F=25.550$, $p < 0.01$) and total dry weight ($F=16.717$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT and the interaction was also significant at 180 days in dry weight

of stem($F=2.778$, $p < 0.01$), leaf ($F=38.459$, $p < 0.01$) and root ($F=10.858$, $p < 0.01$) and total dry weight ($F=44.801$, $p< 0.01$).

Table 21 Effect of biopriming with different concentrations of PGPR II at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

PGPR 2		Fresh weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	0.733^{defgh}	0.803^{defgh}	0.240^{ab}	0.250^{ab}	$0.340^{abcdefg}$	0.370^{bcdefg}	1.323^{a}	1.413^{cdef}
	2	-	-	-	-	-	-	-	-
	3	0.637^{cdefg}	0.707^{cdefg}	0.187^{ab}	0.197^{ab}	$0.373^{bcdefgh}$	$0.403^{bcdefgh}$	1.207^{cd}	1.297^{cd}
	4	0.663^{cdefgh}	0.733^{cdefgh}	0.280^{abc}	0.290^{abc}	0.600^{defghi}	0.630^{defghi}	1.553^{defg}	1.643^{defg}
	6	0.187^{i}	1.257^{i}	0.190^{ab}	0.200^{ab}	0.313^{abcdef}	0.343^{abcdef}	1.700^{efg}	1.790^{efg}
	8	-	-	-	-	-	-	-	-
50%	1	0.440^{bc}	0.510^{bc}	0.137^{ab}	0.307^{abc}	0.237^{abc}	0.267^{abc}	0.983^{bc}	1.073^{bc}
	2	0.547^{cd}	0.617^{cd}	0.153^{ab}	0.163^{ab}	0.263^{abcd}	0.293^{abcd}	0.973^{bc}	1.063^{bc}
	3	-	-	-	-	-	-	-	-
	4	0.610^{cdef}	0.680^{cdef}	0.137^{ab}	0.140^{ab}	0.630^{efghi}	0.660^{efghi}	1.380^{cdefg}	1.470^{cdefg}
	6	0.890^{gh}	0.960^{gh}	0.227^{ab}	0.237^{ab}	0.250^{abc}	0.280^{abc}	1.377^{cdefg}	1.467^{cdefg}
	8	0.577^{cde}	0.647^{cde}	0.637^{c}	0.647^{c}	0.303^{abcde}	0.333^{abcde}	1.527^{defg}	1.617^{defg}
75%	1	1.290^{i}	1.360^{i}	0.320^{abc}	0.330^{abc}	0.780^{i}	0.810^{i}	2.400^{h}	2.490^{h}
	2	0.863^{fgh}	0.933^{fgh}	0.470^{bc}	0.480^{bc}	0.263^{abcd}	0.293^{abcd}	1.607^{defg}	1.697^{defg}
	3	1.280^{ia}	1.350^{i}	0.313^{abc}	0.323^{abc}	0.770^{i}	0.800^{i}	2.373^{h}	2.463^{h}
	4	0.800^{defgh}	0.870^{defgh}	0.330^{abc}	0.340^{abc}	0.653^{fghi}	0.683^{fghi}	1.793^{fg}	1.833^{fg}
	6	0.787^{defgh}	0.857^{defgh}	0.293^{abc}	0.303^{abc}	0.137^{ab}	0.167^{ab}	1.227^{cde}	1.317^{cde}
	8	0.860^{fgh}	0.930^{fgh}	0.283^{abc}	0.293^{abc}	0.630^{efghi}	0.660^{efghi}	1.783^{fg}	1.873^{fg}
100%	1	0.907^{h}	0.977^{h}	0.163^{ab}	0.173^{ab}	$0.377^{bcdefgh}$	$0.407^{bcdefghi}$	1.457^{cdefg}	1.547^{cdefg}
	2	0.800^{defgh}	0.870^{defgh}	0.167^{ab}	0.170^{ab}	$0.520^{cdefghi}$	$0.550^{cdefghi}$	1.490^{defg}	1.580^{defg}
	3	0.840^{efgh}	0.910^{efgh}	0.290^{abc}	0.300^{abc}	0.693^{hi}	0.723^{hi}	1.833^{g}	1.923^{g}
	4	0.813^{defgh}	0.883^{defgh}	0.197^{ab}	0.207^{ab}	0.210^{abc}	0.240^{abc}	1.230^{cde}	1.320^{cde}
	6	0.900^{gh}	0.970^{gh}	0.243^{ab}	0.253^{ab}	0.670^{ghi}	0.700^{ghi}	1.823^{g}	1.913^{g}
	8	0.243^{ab}	0.313^{b}	0.097^{ab}	0.107^{ab}	0.167^{ab}	0.197^{ab}	0.517^{b}	0.607^{b}
SEM		0.0491	0.0491	0.0714	0.0714	0.072	0.0635	0.0888	0.0888

Main effects								
Concentration								
25%	0.537^{A}	0.583^{A}	0.149^{A}	0.156^{A}	0.271^{A}	0.291^{A}	0.964^{A}	1.02^{A}
50%	0.511^{A}	0.569^{A}	0.242^{AB}	0.249^{AB}	0.281^{A}	0.306^{A}	1.040^{A}	1.11^{A}
75%	0.980^{C}	1.050^{C}	0.335^{B}	0.345^{B}	0.539^{A}	0.569^{C}	1.864^{C}	1.95^{C}
100%	0.751^{B}	0.821^{B}	0.194^{A}	0.202^{A}	0.439^{A}	0.469^{B}	1.392^{B}	1.48^{B}
SEM	0.02	0.02	0.0292	0.0294	0.0259	0.0259	0.0362	0.0362
Duration								
1	0.843^{D}	0.912^{D}	0.255^{A}	0.265^{A}	0.433^{BC}	0.463^{BC}	1.541^{C}	1.63^{C}
2	0.552^{B}	0.605^{B}	0.200^{A}	0.203^{A}	0.262^{A}	0.284^{A}	1.018^{A}	1.08^{A}
3	0.689^{C}	0742^{C}	0.198^{A}	0.205^{A}	0.459^{BC}	0.482^{BC}	1.353^{B}	1.42^{B}
4	0.722^{C}	0.792^{C}	0.236^{A}	0.244^{A}	0.523^{C}	0.553^{C}	1.489^{BC}	1.58^{BC}
6	0.941^{D}	1.011^{D}	0.238^{A}	0.248^{A}	0.343^{AB}	0.372^{AB}	1.532^{BC}	1.62^{C}
8	0.420^{A}	0.472^{A}	0.254^{A}	0.262^{A}	0.275^{A}	0.297^{A}	0.957^{A}	1.02^{A}
SEM	0.0245	0.0245	0.0357	0.036	0.0318	0.0318	0.0444	0.0444
Values within the same column with similar superscripts are homogenous								

Table 22 Effect of biopriming with different concentrations of PGPR II at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

PGPR 2		Dry weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
	1	0.343^{bcd}	0.489^{defgh}	0.167^{ab}	0.323^{c}	0.170^{abcdefg}	0.180^{abcde}	0.847^{cdefg}	0.882^{cdef}

25%	2	-	-	-	-	-	-	-	-
	3	0.283^{abcd}	0.424^{cdefg}	0.131^{ab}	0.193^{abc}	0.187^{bcdefgh}	0.186^{abcde}	0.563^{bcde}	0.804^{cd}
	4	0.340^{bcd}	0.442^{cdefgh}	0.143^{abc}	0.197^{abc}	0.250^{defghi}	0.300^{bcde}	0.737^{cdef}	1.036^{defg}
	6	0.707^{f}	0.791^{i}	0.093^{abc}	0.133^{ab}	0.157^{abcdef}	0.183^{abcde}	0.983^{fg}	1.133^{efg}
	8	-	-	-	-	-	-	-	-
50%	1	0.207^{abc}	0.293^{bc}	0.120^{abc}	0.204^{abc}	0.118^{abc}	0.120^{abcd}	0.447^{bc}	0.656^{bc}
	2	0.230^{abc}	0.364^{cd}	0.080^{abc}	0.109^{ab}	0.132^{abcd}	0.177^{abcde}	0.487^{bcd}	0.649^{bc}
	3	-	-	-	-	-	-	-	-
	4	0.197^{abc}	0.407^{cdef}	0.07^{abc}	0.093^{ab}	0.115^{efghi}	0.207^{abcde}	0.473^{bcd}	0.920^{cdefg}
	6	0.363^{bcd}	0.593^{gh}	0.093^{abc}	0.158^{ab}	0.125^{abc}	0.140^{abcd}	0.577^{bcdef}	0.918^{cdefg}
	8	0.270^{abcd}	0.384^{cde}	0.270^{bc}	0.431^{c}	0.152^{abcde}	0.173^{abcd}	0.663^{bcdef}	1.018^{defg}
75%	1	0.720^{f}	0.860^{i}	0.177^{abc}	0.220^{abc}	0.390^{i}	0.663^{f}	1.530^{h}	1.600^{h}
	2	0.410^{bcde}	0.576^{fgh}	0.157^{abc}	0.320^{bc}	0.132^{abcd}	0.147^{abcde}	0.587^{bcdef}	1.071^{defg}
	3	0.720^{f}	0.853^{i}	0.130^{abc}	0.216^{abc}	0.385^{i}	0.447^{e}	1.197^{gh}	1.582^{h}
	4	0.410^{bcde}	0.533^{defgh}	0.157^{abc}	0.227^{abc}	0.327^{fghi}	0.350^{cde}	0.867^{defg}	1.196^{fg}
	6	0.340^{bcd}	0.524^{defgh}	0.137^{abc}	0.22^{abc}	0.068^{ab}	0.083^{ab}	0.560^{bcde}	0.818^{cde}
	8	0.277^{abcd}	0.573^{fgh}	0.127^{abc}	0.196^{abc}	0.215^{efghi}	0.240^{abcde}	0.583^{bcdef}	1.189^{fg}
100%	1	0.557^{def}	0.604^{h}	0.083^{abc}	0.116^{ab}	0.188^{bcdefgh}	0.217^{bcde}	0.857^{cdefg}	0.971^{cdefg}
	2	0.4^{bcde}	0.533^{defgh}	0.087^{abc}	0.113^{ab}	0.260^{cdefghi}	0.287^{bcde}	0.733^{cdef}	0.993^{defg}
	3	0.4^{bcde}	0.560^{efgh}	0.113^{abc}	0.200^{abc}	0.347^{hi}	0.354^{cde}	0.810^{cdefg}	1.222^{g}
	4	0.453^{cdef}	0.542^{defgh}	0.097^{abc}	0.138^{ab}	0.105^{abc}	0.120^{abcd}	0.670^{bcdef}	0.820^{cde}
	6	0.453^{cdef}	0.6^{gh}	0.117^{abc}	0.169^{ab}	0.335^{ghi}	0.373^{de}	0.913^{efg}	1.216^{g}
	8	0.143^{ab}	0.162^{ab}	0.060^{ab}	0.071^{ab}	0.083^{ab}	0.093^{abc}	0.297^{ab}	0.344^{b}
SEM		0.0439	0.0535	0.0472	0.0472	0.0327	0.03918	0.0592	0.0759
Main effects									
Concentration									
25%		0.270^{A}	0.358^{A}	0.1034^{A}	0.104^{A}	0.133^{A}	0.136^{A}	0.522^{A}	0.643^{A}
50%		0.211^{A}	0.340^{A}	0.1056^{A}	0.166^{AB}	0.124^{A}	0.140^{A}	0.441^{A}	0.693^{A}
75%		0.453^{B}	0.653^{C}	0.1472^{A}	0.230^{B}	0.287^{C}	0.269^{C}	0.887^{C}	1.243^{C}
100%		0.406^{B}	0.500^{B}	0.0928^{A}	0.134^{A}	0.214^{B}	0.220^{B}	0.713^{B}	0.928^{B}

SEM	0.0218	0.0134	0.0196	0.0193	0.013	0.016	0.031	0.0242
Duration								
1	0.449^{BC}	0.562^{D}	0.1758^{A}	0.177^{A}	0.217^{BC}	0.295^{C}	0.920^{C}	1.027^{C}
2	0.228^{A}	0.368^{B}	0.0808^{A}	0.136^{A}	0.131^{A}	0.1425^{AB}	0.452^{A}	0.678^{A}
3	0.351^{B}	0.459^{C}	0.0842^{A}	0.137^{A}	0.230^{BC}	0.2475^{B}	0.642^{B}	0.902^{B}
4	0.350^{B}	0.481^{C}	0.1175^{A}	0.163^{A}	0.2192^{BC}	0.262^{C}	0.687^{B}	0.993^{BC}
6	0.473^{C}	0.627^{D}	0.1100^{A}	0.166^{A}	0.170^{AB}	0.171^{AB}	0.758^{B}	1.021^{BC}
8	0.172^{A}	0.280^{A}	0.1142^{A}	0.174^{A}	0.0992^{A}	0.138^{A}	0.386^{B}	0.638^{A}
SEM	0.0268	0.0164	0.0236	0.024	0.0159	0.0196	0.0296	0.0379
Values within the same column with similar superscripts are homogenous								

4.5.3.3. Plant growth analysis indices and vigour index

The effect of biopriming of sandal seedlings with PGPR II at different concentrations and durations on leaf weight ratio, leaf area ratio, and root: shoot ratio and vigour index is given in Table 23. For the first month of observation, the largest LAR was shown by seedlings bioprimed at 100 % for 8 days (10.85 $cm^2 g^{-1}$) and the lowest was shown by seeds bioprimed at 25% for 6 days (1.41 $cm^2 g^{-1}$). At sixth month, seedlings bioprimed at 50 % for 1 day (18.09 $cm^2 g^{-1}$) recorded the highest LAR and the seeds bioprimed at 75 % for 1 day (4.12 $cm^2 g^{-1}$) recorded the lowest LAR. At 30 DAT, the largest LWR was shown by seedlings bioprimed at 100 % for 4 days (0.659) and lowest was at 50 % for 8 days (0.403). At 180 DAT, seedlings bioprimed at 75 % for 6 days (0.672) recorded the highest LWR and biopriming at 50% for 8 days (0.425) recorded the lowest LWR. For the first month of observation, the largest root: shoot ratio was shown by seedlings bioprimed at 50% for 4 days (0.3106) and the lowest on biopriming at 75 % for 6 days (0.0678). At sixth month, seedlings bioprimed at 50% for 4 days (0.763) recorded the highest root: shoot ratio and those at 75 % for 6 days (0.176) recorded the lowest value. The largest VI is shown by seedlings bioprimed at 75 % for 1 day (593.8) and the lowest was on biopriming at 100 % for 8 days (52.3) at 30 DAT. At 180 DAT, seedlings bioprimed at 75% for 1 days (859) recorded the highest VI and the seeds bioprimed at 50% for 8 days (143) recorded the lowest VI. Analysis of variance revealed significant difference in leaf area ratio ($F=2.965$, $p < 0.01$), leaf weight ratio, ($F=21.968$, $p < 0.01$) root: shoot ratio ($F=10.231$, $p < 0.01$) and vigour index ($F=41.647$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT. The interaction was also significant at 180 days in leaf area ratio ($F=6.327$, $p < 0.01$), leaf weight ratio ($F=12.407$, $p < 0.01$) root: shoot ratio ($F=7.647$, $p < 0.01$) and vigour index ($F=62.652$, $p < 0.01$).

Table 23 Effect of biopriming with different concentrations of PGPR II at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

PGPR 2		Leaf Area Ratio (cm2 g-1)		Leaf Weight Ratio		Root : Shoot ratio		Vigor index	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	6.51^{ab}	7.79^{ab}	0.557^{bcde}	0.630^{b}	0.160^{bcd}	0.339^{abc}	414.5^{ef}	664^{gh}
	2	-	-	-	-	-	-	-	-
	3	6.56^{ab}	8.65^{abcd}	0.531^{bcde}	0.606^{bc}	0.196^{bcde}	0.502^{bc}	199.3^{bcd}	301^{bcde}
	4	5.73^{ab}	8.65^{abcd}	0.426^{bc}	0.459^{bc}	0.244^{de}	0.511^{bc}	68.8^{ab}	162^{ab}
	6	1.41^{a}	4.53^{abc}	0.699^{e}	0.714^{c}	0.123^{abcd}	0.234^{ab}	257.7^{cde}	577^{fg}
	8	-	-	-	-	-	-	-	-
50%	1	9.16^{ab}	18.09^{de}	0.447^{bcd}	0.463^{bc}	0.139^{abcd}	0.370^{abc}	292.7^{de}	449^{def}
	2	6.86^{ab}	15.29^{cde}	0.562^{bcde}	0.569^{bc}	0.173^{bcde}	0.573^{bc}	273.8^{de}	453^{def}
	3	-	-	-	-	-	-	-	-
	4	4.84^{ab}	18.09^{de}	0.444^{bcd}	0.464^{b}	0.311^{e}	0.763^{c}	473.1^{fg}	676^{ghi}
	6	3.60^{ab}	15.29^{cde}	0.647^{de}	0.720^{bc}	0.116^{abcd}	0.272^{ab}	139.9^{abcd}	249^{bc}
	8	6.21^{ab}	7.50^{abc}	0.403^{b}	0.425^{b}	0.118^{abcd}	0.247^{ab}	54.7^{ab}	143^{ab}
75%	1	1.85^{ab}	4.12^{abc}	0.538^{bcde}	0.656^{bc}	0.214^{bcde}	0.774^{c}	593.8^{gh}	859^{ib}
	2	5.38^{ab}	11.17^{abcd}	0.538^{bcde}	0.579^{bc}	0.094^{abc}	0.346^{abc}	110.7^{abc}	243^{bc}
	3	4.61^{ab}	5.89^{abcd}	0.544^{bcde}	0.605^{bc}	0.217^{bcde}	0.405^{abc}	274.8^{de}	478^{ef}
	4	5.96^{ab}	6.25^{abcd}	0.446^{bcd}	0.473^{bc}	0.230^{cde}	0.531^{bc}	279.1^{de}	404^{cdef}
	6	5.56^{ab}	6.64^{abcd}	0.641^{cde}	0.672^{bc}	0.068^{ab}	0.176^{ab}	483.5^{fgh}	827^{hi}
	8	5.48^{ab}	8.36^{abcd}	0.483^{bcde}	0.494^{b}	0.230^{cde}	0.434^{abc}	171.5^{bcd}	304^{bcde}
100%	1	6.01^{ab}	7.28^{abc}	0.621^{bcde}	0.635^{bc}	0.179^{bcde}	0.389^{abc}	295.6^{de}	467^{def}
	2	3.51^{ab}	4.21^{abc}	0.554^{bcde}	0.595^{bc}	0.230^{cde}	0.500^{bc}	597.7^{gh}	840^{hi}
	3	3.95^{ab}	9.49^{abcd}	0.458^{bcd}	0.492^{bc}	0.244^{de}	0.578^{bc}	637.8^{h}	848^{i}
	4	6.83^{ab}	12.38^{bcde}	0.659^{de}	0.670^{bc}	0.114^{abcd}	0.232^{ab}	148.1^{abcd}	257^{bc}
	6	4.93^{ab}	5.88^{abc}	0.494^{bcde}	0.528^{bc}	0.244^{de}	0.560^{bc}	155.6^{abcd}	290^{bcd}
	8	10.85^{b}	11.94^{abcd}	0.501^{bcde}	0.544^{bc}	0.177^{bcde}	0.458^{bc}	52.3^{ab}	146^{ab}
SEM		1.68	2.25	0.0402	0.0508	0.0274	0.0807	29.5	33.5

Main effects								
Concentration								
25%	3.37^{a}	4.10^{a}	0.351^{a}	0.369^{a}	0.121^{a}	0.264^{a}	157^{a}	284^{a}
50%	5.11^{ab}	13.09^{b}	0.4^{a}	0.417^{a}	0.143^{ab}	0.3710^{ab}	206^{b}	328^{a}
75%	4.81^{ab}	7.07^{a}	0.507^{b}	0.532^{b}	0.175^{bc}	0.445^{b}	319^{c}	519^{b}
100%	6.01^{b}	7.36^{a}	0.561^{b}	0.548^{b}	0.198^{c}	0.453^{b}	315^{c}	475^{b}
SEM	0.688	0.918	0.0164	0.0207	0.0112	0.00329	12	13.7
Duration								
1	5.88^{a}	8.8^{ab}	0.495^{b}	0.541^{cd}	0.173^{ab}	0.468^{bc}	399.2^{c}	610^{d}
2	3.94^{a}	7.72^{ab}	0.376^{a}	0.414^{ab}	0.124^{a}	0.355^{abc}	245.6^{b}	384^{b}
3	3.78^{a}	6.01^{a}	0.301^{ab}	0.383^{a}	0.164^{a}	0.371^{abc}	278^{b}	407^{b}
4	5.84^{a}	11.35^{b}	0.406^{b}	0.494^{bc}	0.224^{b}	0.509^{c}	242.3^{b}	375^{b}
6	3.88^{a}	7.58^{ab}	0.616^{c}	0.620^{d}	0.138^{a}	0.3110^{ab}	259.2^{b}	486^{c}
8	5.63^{a}	5.95^{a}	0.333^{a}	0.347^{a}	0.131^{a}	0.285^{a}	69.6^{a}	148^{a}
SEM	0.842	1.12	0.0201	0.0254	0.0137	0.0403	14.7	16.7
Values within the same column with similar superscripts are homogenous								

4.5.4. Hydropriming

4.5.4.1 Seedling growth

The impact of hydropriming at different durations on the shoot parameters of sandal seedlings are presented in Table 24. At 30 DAT, the highest seedling height was shown by seedlings hydroprimed for 8 days (10.6 cm) and the lowest was in that for 4 days (4.8 cm). At 180 DAT also the seedlings hydroprimed for 8 days (18 cm) recorded the highest seedling height and those for 4 days (12.2 cm) recorded the lowest value. Whereas, the largest collar diameter was shown by seedlings hydroprimed for 8 days (1.580 mm) and the lowest value was for 4 days (0.983 mm) at 30 DAT. At 180 DAT, seeds hydroprimed for 8 days (2.71 mm) recorded the highest collar diameter and the seeds hydroprimed for 4 days (2.11 mm) recorded the lowest. The highest leaf number At 30 DAT was shown by seedlings hydroprimed for 4 days and 6 days (18.33) and the lowest was in 1 day (9.67). At 180 DAT, seeds hydroprimed for 4 and 6 days (22.3) recorded the highest leaf number and the seeds hydroprimed for 1 day recorded the lowest (13.7). For first month the largest leaf area is shown by seedlings hydroprimed for 8 days (5.47 cm ^{2}) and the lowest was for 1day (2.57 cm ^{2}). At sixth month, seeds hydroprimed for 1day (7.76 cm ^{2}) recorded the highest leaf area and the seeds hydroprimed for 6days (5.08 cm ^{2}) recorded the lowest value. Analysis of variance revealed significant difference in seedling height ($F=31.498$, $p < 0.01$), collar diameter ($F=28.984$, $p < 0.01$) and leaf area ($F=7.894$, $p<0.01$) due to hydropriming duration at 30 DAT. At 180 DAT also seedling height ($F=95.370$, $p < 0.01$), collar diameter ($F=9.835$, $p<0.01$), leaf number ($F=63.778$, $p<0.01$) and leaf area ($F=13.274$, $p < 0.0$) of the seedlings varied with hydropriming duration.

The impact of hydropriming durations on the root parameters of sandal seedlings are presented in Table 25. For first month the highest root length was shown by seedlings hydroprimed for 8 days (19.97 cm) and the lowest was for 1 day (1.10 cm). Seedlings hydroprimed for 8 days (24.27 cm) recorded the highest root length and the lowest root length was for 1 day soaking (5.40 cm) at sixth month. The largest number of roots at 30 DAT was present in seedlings hydroprimed for 8 days (9) and the lowest was in hydropriming for 6 days (2.33). At 180 DAT, seeds hydroprimed for 8 days (11) recorded the highest number of roots and the seeds hydroprimed for 2 days (3.33) recorded the lowest value.

For first month, the largest total seedling length was shown by seedlings hydroprimed for 8 days (30.60 cm) and the lowest was in hydropriming for 1 day (6.70 cm). At sixth month, seeds hydroprimed for 8 days (42.3 cm) recorded the highest total seedling length and the seeds hydroprimed for 1day (18.4 cm) recorded the lowest value.

Analysis of variance revealed significant difference in root length ($F=334.88$, $p < 0.01$), root number ($F=9.030$, $p < 0.01$) and total seedling length ($F=119.229$, $p<0.01$) due to hydropriming duration at 30 DAT. At 180 DAT also root length ($F=416.979$, $p < 0.01$), root number ($F=13.485$, $p < 0.01$) and total seedling length ($F=201.384$, $p<0.01$) of the seedlings varied with hydropriming duration.

Table 24 Effect of hydropriming at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Hydropriming (Days)	Shoot height (cm)		Collar Girth (mm)		Leaf number		Leaf Area (cm^2)	
	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT
1	5.60^{b}	13.00^{b}	0.99^{b}	2.12^{b}	9.67^{b}	13.7^{b}	2.57^{ab}	7.76^{d}
2	6.60^{bc}	14.00^{bc}	1.43^{bc}	2.56^{bc}	16.67^{c}	20.7^{c}	3.55^{abc}	5.85^{bcd}
3	-	-	-	-	-	-	-	-
4	4.80^{b}	12.20^{b}	0.98^{b}	2.11^{b}	18.33^{c}	22.3^{c}	3.90^{abc}	6.54^{c}
6	8.70^{cd}	16.10^{cd}	1.23^{bc}	2.36^{bc}	18.33^{c}	22.3^{c}	4.63^{bc}	5.08^{c}
8	10.60^{d}	18.00^{d}	1.58^{c}	2.71^{c}	16.00^{c}	20.0^{c}	5.47^{bc}	6.82^{cd}
SEM	0.651	0.651	0.104	0.104	1.09	1.09	0.827	0.781
Values within the same column with similar superscripts are homogenous.								

Table 25 Effect of hydropriming at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Hydropriming (Days)	Number of Lateral Roots		Root Length (cm)		Total Seedling Length	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	3.33^{a}	3.67^{ab}	1.10^{ab}	5.40^{b}	6.70^{b}	18.4^{b}
2	3.00^{a}	3.33^{ab}	2.57^{bc}	6.87^{bc}	9.17^{b}	20.9^{b}
3	-	-	-	-	-	-
4	4.00^{a}	6.00^{b}	4.43^{c}	8.73^{c}	9.23^{b}	20.9^{b}
6	2.33^{a}	3.67^{ab}	7.80^{d}	12.10^{d}	16.50^{c}	28.2^{c}
8	9.00^{b}	11.00^{c}	19.97^{e}	24.27^{d}	30.60^{d}	42.3^{d}
SEM	0.991	1.12	0.403	0.403	0.964	0.964
Values within the same column with similar superscripts are homogenous.						

4.5.4.2. Biomass production

Variation in fresh weight of seedlings obtained after hydropriming for different durations is presented in Table 26. For first month, the largest stem fresh weight was shown by seedlings hydroprimed for 1 day (0.420 g) and the lowest in 2 days (0.130 g). At sixth month, seeds hydroprimed at 1 day (0.430 g) recorded the highest and the seeds hydroprimed for 2 days (0.133 g) recorded the lowest stem fresh weight. The highest leaf fresh weight was recorded by seedlings hydroprimed for 4 days (0.880 g) and the lowest in hydropriming for1 day (0.0867 g) at 30 DAT. At 180 days, seeds hydroprimed at for 4 days (0.950 g) recorded the highest those for 1 day (0.157 g) recorded the lowest leaf fresh weight. At 30 DAT, root fresh weight was highest in the seedlings hydroprimed for 4 days (0.323 g) and the lowest was in hydropriming for 1day (0.123 g). At 180 DAT, seeds hydroprimed at for 4 days (0.353 g) recorded the highest fresh root weight and 1 day (0.153 g) soaking registered the lowest value. Regarding the total fresh weight, the highest value was shown in seedlings hydroprimed for 4 days (1.397 g) and the lowest was in hydropriming for 8 days (0.593 g) at 30 DAT. At 180 DAT, seeds hydroprimed at for 4 days (1.487 g) recorded the highest total fresh weight and the seeds hydroprimed for 8 days (0.647 g) recorded the lowest total fresh weight. Statistical analysis revealed significant difference in fresh weight of stem ($F=4.743$, $p < 0.01$), leaf ($F=187.752$, $p < 0.05$) and root ($F=9.912$, $p < 0.01$) and total fresh weight ($F=32.812$, $p < 0.01$) due to hydropriming duration at 30 DAT and the variation was also significant at 180 days in fresh weight of stem ($F=4.859$, $p < 0.05$), leaf ($F=204.679$, $p < 0.01$) and root ($F=11.383$, $p < 0.01$) and total fresh weight ($F=35.251$, $p< 0.01$).

Variation in dry weight biomass of hydroprimed seedlings are presented in Table 27. For the first month, the largest stem dry weight was shown by seedlings hydroprimed for 1day (0.1933 g) and the lowest was in hydropriming for 2 days (0.0833 g). At sixth month, seeds hydroprimed for1day (0.2867 g) recorded the highest stem dry weight and the lowest seeds was for 2 days (0.0899 g).While the maximum leaf dry weight was shown by seedlings hydroprimed for 4 days (0.433 g) and lowest was for 1 day (0.0578 g) at 30 DAT. At 180 DAT also, the hydropriming for 4 days (0.5867 g) recorded the highest dry weight (leaf) and the lowest was for 1 day (0.090 g). For first month the largest root dry weight was shown by seedlings hydroprimed for 4 days (0.1617 g) and the lowest was for1 day (0.0617 g) soaking. At sixth month, hydropriming for 6 days (0.1733 g) recorded the highest root dry weight and the lowest was for 1 day (0.07 g). Regarding total dry weight at 30 DAT, largest total dry weight was shown by seedlings hydroprimed for4 days (0.697 g) and the lowest for1 day and 8 days (0.353 g). At 180 DAT, seeds hydroprimed for 4 days (0.9310 g) recorded the highest total dry weight and that for 8 days (0.396 g) recorded the lowest value. Statistical analysis revealed significant difference in dry weight of stem ($F=4.642$, $p <0.05$), leaf ($F=186.856$, $p < 0.01$) ,root ($F=10.301$, $p < 0.01$) and total dry weight ($F=33.078$, $p < 0.01$) due to hydropriming duration at 30 DAT and the effect of duration was also significant at 180 days in dry weight of stem($F=4.104$, $p < 0.05$), leaf ($F=76.810$, $p < 0.01$) and root ($F=14.834$, $p < 0.01$) and total dry weight ($F=31.798$, $p< 0.01$).

Table 26 Effect of hydropriming at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Hydropriming (Days)	Fresh Weight (g)							
	Leaf		Shoot		Root		Seedling	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	0.087^{ab}	0.157^{b}	0.420^{b}	0.430^{b}	0.123^{ab}	0.153^{ab}	0.640^{b}	0.730^{b}
2	0.463^{c}	0.533^{c}	0.130^{ab}	0.133^{ab}	0.290^{bc}	0.320^{bc}	0.887^{bc}	0.983^{bc}
3	-	-	-	-	-	-	-	-
4	0.880^{e}	0.950^{e}	0.183^{ab}	0.193^{ab}	0.323^{c}	0.353^{c}	1.397^{d}	1.487^{d}
6	0.687^{d}	0.757^{d}	0.217^{ab}	0.227^{ab}	0.293^{bc}	0.323^{ab}	1.207^{cd}	1.297^{cd}
8	0.153^{b}	0.223^{b}	0.267^{ab}	0.313^{ab}	0.127^{ab}	0.157^{ab}	0.593^{b}	0.647^{b}
SEM	0.026	0.026	0.0636	0.0679	0.0409	0.0409	0.026	0.026
Values within the same column with similar superscripts are homogenous.								

Table 27 Effect of hydropriming at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Hydropriming (Days)	Dry Weight (g)							
	Leaf		Shoot		Root		Total	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	0.058^{ab}	0.090^{b}	0.193^{b}	0.287^{b}	0.062^{ab}	0.07^{ab}	0.353^{b}	0.427^{b}
2	0.109^{b}	0.227^{c}	0.083^{ab}	0.089^{ab}	0.145^{bc}	0.147^{bcd}	0.457^{bc}	0.591^{bc}
3	-	-	-	-	-	-	-	-
4	0.433^{d}	0.587^{e}	0.113^{ab}	0.129^{ab}	0.162^{c}	0.170^{cd}	0.697^{d}	0.931^{d}
6	0.287^{c}	0.458^{d}	0.107^{ab}	0.151^{ab}	0.147^{bc}	0.173^{d}	0.567^{cd}	0.804^{cd}
8	0.102^{b}	0.130^{b}	0.137^{ab}	0.209^{ab}	0.063^{ab}	0.087^{bc}	0.353^{b}	0.396^{b}
SEM	0.0173	0.0176	0.0315	0.0453	0.0205	0.0168	0.0422	0.0579
Values within the same column with similar superscripts are homogenous.								

4.5.4.3. Plant growth analysis indices and vigour index

Variation in plant growth analysis indices and vigour index of the seedlings subjected to hydropriming are given in Table 28. For the first month the largest LAR was shown by seedlings hydroprimed for 8 days (13.85 $cm^2 g^{-1}$)) and lowest was for 6 days (5.98 $cm^2 g^{-1}$). At sixth month, seedlings hydroprimed for 1 day (24.54 $cm^2 g^{-1}$) recorded the highest LAR and the seedlings hydroprimed for 6 days (6.46 $cm^2 g^{-1}$) recorded the lowest value. Meanwhile, the largest leaf weight ratio was shown by seedlings hydroprimed for 4 days (0.635) and lowest was for 1 day (0.149) soaking at 30 DAT. At sixth month, seeds hydroprimed for 4 days (0.639) recorded the highest LWR and the lowest was in 1 day (0.272) soaking. Variation in root: shoot ratio of hydroprimed seedlings indicated that largest root: shoot ratio at 30 DAT was shown by seedlings hydroprimed for 2 days (0.213) and the lowest was shown by seeds hydroprimed for 8 days (0.106). At 180 DAT, seedlings hydroprimed for 2 days (0.476) recorded the highest root: shoot ratio and that for 4 days (0.270) recorded the lowest root: shoot ratio. The largest vigour index at 30 DAT was shown by seedlings hydroprimed for 8 days (877.2) and the lowest for 1 day (34.9) soaking. At 180 DAT, seeds hydroprimed for 8 days (1212.6) recorded the highest VI and the seeds hydroprimed for 4 days (83.7) recorded the lowest vigour index.

Analysis of variance revealed significant difference in leaf area ratio ($F=3.214$, $p < 0.05$), leaf weight ratio ($F=47.657$, $p < 0.01$) root: shoot ratio ($F=6.618$, $p < 0.01$) and vigour index ($F=491.200$, $p < 0.01$) due to hydropriming duration at 30 DAT. The duration was also significant at 180 days in leaf area ratio ($F=8.426$, $p < 0.01$), leaf weight ratio ($F=33.435$, $p < 0.01$) root: shoot ratio ($F=5.877$, $p < 0.01$) and vigour index ($F=680.821$, $p < 0.01$).

Table 28 Effect of hydropriming at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one day.

Hydropriming (Days)	Leaf Area Ratio ($cm^2 g^{-1}$)		Leaf Weight Ratio		Root : Shoot Ratio		Vigour index	
	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT
1	8.52^{ab}	24.54^{c}	0.149^{ab}	0.272^{b}	0.109^{ab}	0.314^{ab}	34.9^{a}	97.3^{b}
2	6.22^{ab}	12.76^{abc}	0.527^{c}	0.597^{cd}	0.213^{b}	0.476^{b}	116.4^{b}	264.6^{c}
3	-	-	-	-	-	-	-	-
4	6.97^{ab}	7.79^{ab}	0.635^{c}	0.639^{d}	0.151^{b}	0.270^{ab}	36.9^{a}	83.7^{b}
6	5.98^{ab}	6.46^{ab}	0.572^{c}	0.616^{d}	0.153^{b}	0.450^{b}	306^{c}	524.4^{d}
8	13.85	19.38^{bc}	0.253^{b}	0.365^{bc}	0.106^{ab}	0.332^{ab}	877.2^{d}	1212.6^{e}
SEM	2.49	3.21	0.0374	0.0385	0.0277	0.0703	15.2	17.5
Values within the same column with similar superscripts are homogenous.								

4.6. The effect of biopriming in seedling growth attributes for the seeds subjected to post priming storage of one week

4.6.1. Biopriming with *Pseudomonas fluorescens*

4.6.1.1. Seedling growth

The impact of biopriming with *Pseudomonas fluorescens* on the shoot parameters of sandal seedlings is presented in Table 29. At 30 DAT, shoot height was highest in the seedlings bioprimed at 100% for 8 days (20.23 cm) and those at 50% for 6days (4.20 cm) recorded the lowest seedling height. Similarly, during 6th month, seedlings bioprimed at 100% for 8 days (28.1 cm) recorded the highest value and the lowest was at 50% for 6 days (12.1 cm).With regard to collar diameter, the largest was shown in seedlings bioprimed at 100% for 8 days (4.443 mm) and the lowest was shown in in seeds bioprimed at 75% for 3 days (0.273 mm) at 30 DAT. At 180 DAT, seedlings obtained after biopriming at 100% for 8 days (5.63 mm) recorded the highest collar diameter and the seeds bioprimed at 75% for 3 days (1.24mm) recorded the lowest value (Table 29). The largest leaf number was shown in in seedlings bioprimed at 100 % for 8 days (22.3) and the lowest was shown in those at 25% for 8 days (14) for the first month of observation. During 6th month also, seeds bioprimed at 100% for 8 days (26.3) recorded the highest leaf number and the seeds bioprimed at 25 % for 8 days (18) recorded the lowest leaf number. However, the largest leaf area was recorded in seedlings bioprimed at 100 % for 3 days (8.16 cm^2) and the lowest was shown in seeds bioprimed at 50% for 3 days (2.09 cm^2) at 30 DAT and at 180 DAT, seeds bioprimed at for days recorded the highest leaf area followed in seeds bioprimed at 75% for 4 days (10.76 cm^2) and the seeds bioprimed at 25 % for 4 days (2.73 cm^2) recorded the lowest leaf area. Treating seeds with *Pseudomonas fluorescens* at 100% for 8 days recorded the highest values for most of the shoot attributes.

The effects of biopriming with different concentrations and durations on root growth attribute of seedlings is given in Table 30.The largest root length was shown in in seedlings bioprimed at 100% for 8 days (12.8 cm) at 30 DAT and 180 DAT (17.7 cm) and the lowest was shown in in seed bioprimed at 75% for 3days (2.6 cm) at 30 DAT and at 180 DAT (7.5 cm). The seedlings bioprimed at 100 % for 8 days (7.33) recorded the highest root number, and the lowest was shown in seed bioprimed at 50 % for 1, 2 and3 days and 75% for 3 days (2.33) at 30 DAT. During 6th month, seeds bioprimed at 100% for 8 days (17.7) recorded the highest number of roots and the seeds bioprimed at 75 % for 3 days (7.5) recorded the lowest number of roots. For the first month of observation, the highest total seedling length was shown in in seedlings bioprimed at 100% for 8 days (33.03 cm) and total seedling length was shown in seeds bioprimed at 75% for 3days (8.37 cm). During 6th month, seeds bioprimed at 100% for 8 days (45.8 cm) recorded the highest total seedling length and the seeds bioprimed at 75% for 3 days (21.2 cm) recorded the total seedling length. A trend similar to shoot parameters was also evident in root parameters and seedling length.

Analysis of variance revealed significant differences in shoot height ($F=9.490$, $p< 0.01$), collar diameter ($F=3.560$, $p < 0.01$), number of leaves ($F=10.446$, $p < 0.01$), root length ($F=4.544$, $p< 0.01$) and total seedling length($F=8.066$, $p < 0.01$) but leaf area ($F=1.415$, $p =0.179$), number of roots ($F=0.967$, $p=0.502$), were not significant at 30 DAT. At 180 DAT also the interaction effect between concentration and duration was significant in shoot height ($F=16.001$, $p< 0.01$), collar diameter ($F=5.045$, $p < 0.01$) , number of leaves

(F=15.184, $p < 0.01$), leaf area (F=7.079, $p< 0.01$), root length (F=6.949, $p < 0.01$) and total seedling length (F=13.643, $p <0.01$) but in the number of roots (F=1.551, p=0.125) the effect was not significant.

Table 29 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Pseudomonas fluorescens		Shoot Height (cm)		Collar Girth (mm)		Number of Leaves		Leaf Area (cm^2)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-	-	-
	2	12.63^{cde}	20.50^{cde}	1.85^{a}	3.04^{bc}	15.71	19.70^{bc}	2.95^{ab}	5.17^{abc}
	3	-	-	-	-	-	-	-	-
	4	7.23^{abcd}	15.10^{bcd}	0.69^{a}	1.66^{ab}	16.70^{bc}	20.70^{bc}	2.62^{ab}	2.73^{ab}
	6	8.10^{bcd}	16.00^{bcd}	0.87^{a}	2.06^{ab}	18.00^{bc}	22.00^{bc}	6.09^{ab}	7.87^{bc}
	8	12.67^{cde}	20.60^{cde}	0.99^{a}	2.18^{ab}	14.00^{b}	18.00^{b}	4.24^{ab}	8.52^{bc}
50%	1	12.97^{cde}	20.90^{cde}	1.47^{a}	2.66^{b}	15.30^{bc}	19.30^{bc}	5.26^{ab}	6.30^{abc}
	2	7.30^{abcd}	15.20^{bcd}	1.34^{a}	2.45^{ab}	17.70^{bc}	21.70^{bc}	4.18^{ab}	6.34^{abc}
	3	12.10^{bcd}	20.00^{bcd}	1.98^{ab}	3.17^{bc}	16.31^{bc}	20.30^{bc}	2.09^{ab}	7.20^{bc}
	4	10.13^{bcd}	18.00^{bcd}	2.26^{ab}	3.45^{bc}	15.30^{bc}	19.30^{bc}	6.72^{ab}	2.09^{ab}
	6	4.20^{ab}	12.10^{b}	1.78^{a}	2.97^{b}	14.70^{bc}	18.70^{bc}	3.79^{ab}	7.32^{bc}
	8	6.13^{abc}	14.00^{bc}	0.84^{a}	1.53^{ab}	14.30^{b}	18.30^{b}	5.35^{ab}	4.65^{abc}
75%	1	10.70^{bcd}	18.60^{bcd}	1.63^{a}	2.82^{b}	15.70^{bc}	19.70^{bc}	4.73^{ab}	6.56^{abc}
	2	10.13^{bcd}	18.00^{bcd}	0.66^{a}	1.65^{ab}	16.70^{bc}	20.70^{bc}	3.23^{ab}	4.40^{abc}
	3	5.77^{abc}	13.70^{bc}	0.27^{a}	1.24^{ab}	15.00^{bc}	19.00^{bc}	3.85^{ab}	4.03^{abc}
	4	10.17^{bcd}	18.10^{bcd}	1.25^{a}	2.44^{ab}	16.70^{bc}	20.70^{bc}	4.40^{ab}	10.76^{c}
	6	6.80^{abc}	14.70^{bc}	0.90^{a}	2.09^{ab}	18.30^{bc}	22.30^{bc}	3.51^{ab}	7.444^{bc}
	8	9.00^{bcd}	16.90^{bcd}	1.51^{a}	2.70^{b}	15.00^{bc}	19.00^{bc}	4.29^{ab}	5.93^{abc}
100%	1	8.43^{bcd}	16.30^{bcd}	0.64^{a}	1.83^{ab}	16.70^{bc}	20.70^{bc}	2.96^{ab}	7.75^{bc}
	2	7.13^{abcd}	15.00^{bcd}	0.89^{a}	2.08^{ab}	16.00^{bc}	20.00^{bc}	6.00^{ab}	8.58^{bc}
	3	5.57^{abc}	13.50^{bc}	2.10^{ab}	3.30^{bc}	20.00^{bc}	24.00^{bc}	8.16^{b}	8.55^{bc}
	4	12.03^{bcd}	19.90^{bcd}	1.76^{a}	2.95^{b}	15.70^{bc}	19.70^{bc}	4.56^{ab}	6.44^{abc}
	6	14.87^{de}	22.80^{de}	1.23^{a}	2.42^{ab}	15.70^{bc}	19.70^{bc}	6.66^{ab}	6.67^{abc}
	8	20.23^{e}	28.10^{e}	4.44^{b}	5.63^{c}	22.30^{c}	26.30^{c}	6.34^{ab}	7.09^{bc}
SEM		1.48	1.48	0.474	0.482	1.43	1.43	1.49	1.26

Main effects								
Concentration								
25%	6.77^{A}	12^{A}	0.735^{A}	1.49^{A}	10.7^{A}	13.4^{A}	2.65^{A}	4.05^{A}
50%	8.81^{A}	16.7^{B}	1.613^{BC}	2.71^{BC}	15.6^{B}	19.6^{B}	4.56^{AB}	5.65^{AB}
75%	8.76^{A}	16.7^{B}	1.036^{AB}	2.16^{AB}	16.2^{B}	20.2^{B}	4^{AB}	6.52^{B}
100%	11.38^{B}	19.3^{C}	1.845^{C}	3.04^{C}	17.7^{B}	21.7^{B}	5.78^{B}	6.67^{B}
SEM	0.604	0.604	0.194	0.197	0.582	0.582	0.061	0.513
Duration								
1	8.03^{AB}	13.9^{AB}	0.936^{A}	1.83^{A}	11.9^{A}	14.9^{A}	3.24^{A}	5.15^{AB}
2	9.30^{BC}	17.2^{CD}	1.184^{AB}	2.31^{AB}	16.5^{B}	20.5^{B}	4.09^{A}	6.12^{AB}
3	5.86^{A}	11.8^{A}	1.091^{AB}	1.93^{A}	12.8^{A}	15.8^{A}	3.52^{A}	3.69^{A}
4	9.89^{BC}	17.8^{CD}	1.492^{AB}	2.63^{AB}	16.10^{B}	20.1^{B}	4.57^{A}	5.5^{AB}
6	8.49^{AB}	16.4^{BC}	1.194^{AB}	2.38^{AB}	16.7^{B}	20.7^{B}	5.01^{A}	7.31^{B}
8	12.01^{C}	19.9^{D}	1.947^{B}	3.01^{B}	16.4^{B}	20.4^{B}	5.05^{A}	6.55^{B}
SEM	0.739	0.739	0.237	0.241	0.713	0.713	0.747	0.628
Values within the same column with similar superscripts are homogenous								

Table 30 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Pseudomonas florescence		Root Length (cm)		Number of Lateral Roots		Total Seedling Length (cm)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-
	2	8.07^{bcde}	12.97^{bcdef}	5.00^{ab}	12.97^{bcdef}	20.70^{bcdef}	33.50^{bcdef}
	3	-	-	-	-	-	-

	4	1.64^{abcde}	11.33^{bcdef}	3.33^{ab}	11.33^{bcdef}	13.67^{abcde}	26.50^{bcde}
	6	4.57^{abcd}	9.47^{bcde}	3.00^{ab}	9.47^{bcde}	12.67^{abcd}	25.50^{bcd}
	8	7.43^{abcde}	12.33^{bcdef}	2.67^{ab}	12.33^{bcdef}	20.10^{bcdef}	32.90^{bcdef}
50%	1	11.53^{cde}	16.43^{def}	2.33^{ab}	16.43^{def}	24.50^{def}	37.30^{def}
	2	4.73^{abcd}	8.70^{bc}	2.33^{ab}	8.70^{bc}	12.03^{abcd}	23.90^{bcd}
	3	6.43^{abcde}	11.33^{bcdef}	2.33^{ab}	11.33^{bcdef}	18.53^{bcde}	31.30^{bcde}
	4	7.13^{abcde}	12.03^{bcdef}	6.00^{ab}	12.03^{bcdef}	17.27^{bcde}	30.10^{bcde}
	6	5.33^{abcde}	10.23^{bcde}	3.00^{ab}	10.23^{bcdef}	9.53^{abc}	22.30^{bc}
	8	4.33^{abc}	9.23^{bcde}	3.33^{ab}	9.23^{bcde}	10.47^{abc}	23.30^{bc}
75%	1	5.47^{abcde}	10.37^{bcdef}	3.00^{ab}	10.37^{bcdef}	16.17^{bcde}	29.00^{bcde}
	2	5.60^{abcde}	10.50^{bcdef}	4.33^{ab}	10.50^{bcdef}	15.73^{bcde}	28.50^{bcde}
	3	2.60^{ab}	7.50^{ab}	2.33^{ab}	7.50^{ab}	8.37^{ab}	21.20^{b}
	4	6.23^{abcde}	11.13^{bcdef}	3.33^{ab}	11.13^{bcdef}	16.40^{bcde}	29.20^{bcde}
	6	4.70^{abcd}	9.60^{bcde}	3.33^{ab}	9.60^{bcde}	11.50^{abcd}	24.30^{bcd}
	8	4.07^{abc}	8.97^{bcd}	4.00^{ab}	8.971^{bcd}	13.07^{abcde}	25.90^{bcde}
100%	1	4.20^{abc}	9.10^{bcd}	7.00^{ab}	9.10^{bcd}	12.63^{abcd}	25.40^{bcd}
	2	10.20^{cde}	15.10^{bcdef}	6.33^{ab}	15.10^{bcdef}	17.33^{bcde}	30.10^{bcde}
	3	4.37^{abc}	9.27^{bcde}	4.67^{ab}	9.27^{bcde}	9.93^{abc}	22.70^{bc}
	4	10.50^{cde}	15.40^{cdef}	4.67^{ab}	15.40^{cdef}	22.53^{cdef}	35.30^{cdef}
	6	12.00^{de}	16.90^{ef}	7.00^{ab}	16.90^{ef}	26.87^{ef}	39.70^{ef}
	8	12.8^{e}	17.70^{f}	7.33^{b}	17.70^{f}	33.03^{f}	45.80^{f}
SEM		1.38	1.42	1.29	1.42	2.55	2.55
Main effects							
Concentration							
25%		4.42^{A}	7.68^{A}	2.33^{A}	7.68^{A}	11.2^{A}	19.7^{A}
50%		6.58^{B}	11.33^{B}	3.22^{A}	11.33^{B}	15.4^{B}	28^{B}
75%		4.78^{AB}	9.68^{AB}	3.39^{A}	9.68	13.5^{AB}	26.3^{B}
100%		9.01^{C}	13.91^{C}	6.17^{B}	13.91^{C}	20.4^{C}	33.2^{C}
SEM		0.562	0.579	0.529	0.579	1.04	1.04
Duration							

1	5.3^{AB}	8.97^{AB}	3.08^{A}	8.97^{AB}	13.32^{AB}	22.9^{AB}
2	7.15^{B}	11.82^{BC}	4.50^{A}	11.82^{BC}	16.45^{BC}	29^{C}
3	3.35^{A}	7.03^{A}	2.33^{A}	7.03^{A}	98.21^{A}	18.8^{A}
4	7.58^{B}	12.47^{C}	4.33^{A}	12.47^{C}	17.47^{BC}	30.3^{C}
6	6.65^{B}	11.55^{BC}	4.08^{A}	11.55^{BC}	15.14^{BC}	27.9^{BC}
8	7.16^{B}	12.06^{C}	4.33^{A}	12.06^{C}	19.17^{C}	32^{C}
SEM	0.688	0.709	0.647	0.709	1.27	1.28
Values within the same column with similar superscripts are homogenous						

4.6.1.2. Biomass production

Variation in fresh weight seedlings of bioprimed with *Pseudomonas fluorescens* at different concentrations and durations are presented in Table 31. Analysis of variance revealed significant difference in fresh weight of the stem ($F=12.885$, $p < 0.01$) , leaf ($F=3.225$, $p < 0.01$), root ($F=6.208$, $p < 0.01$) and total fresh weight ($F=9.219$, $p < 0.01$) at 30 DAT and at 180 DAT also, fresh weight of stem (($F=18.096$, $p < 0.01$), fresh weight of leaf ($F=8.018$, $p < 0.01$), root ($F=8.276$, $p < 0.01$) and total plant ($F=16.427$, $p< 0.01$) varied due to the interaction between bioinoculant concentration and duration.

For the first month of observation, the largest stem fresh weight was shown in seedlings bioprimed at 100% for 1 day (0.3533 g) and the lowest was shown in those at 50% for 2 days (0.024 g). During the 6th month, seedlings bioprimed at for 100% for 1 day (0.4633 g) recorded the highest stem weight and those at 75 % for 3 days (0.0733 g) recorded the lowest value. At 30 DAT, the largest leaf fresh weight was shown in seedlings bioprimed at 100 % for 6 days (0.7667 g) and the lowest was shown in that at 75% for 4 days (0.0733 g). At 180 DAT also seeds bioprimed at 100% % for 6 days (0.957 g) recorded the highest fresh weight (leaf) and but those at 75 % for 4 days (0.147 g) recorded the lowest value. Meanwhile, for the first month of observation the largest root fresh weight was recorded in seedlings bioprimed at 50% for 4 days (0.46 g) and the lowest was in at 50% for 8 days and 75% for 4 days (0.07 g). Similarly, at 180 DAT, seeds bioprimed at 50% for 4 days (0.5467 g) recorded the highest fresh weight (root) and the seeds bioprimed at 75 % for 4 days (0.09 g) recorded the lowest weight. The largest total fresh weight at 30 DAT was is shown in seedlings bioprimed at 100% for 6 days (1.223 g) and the lowest value was shown in seedlings bioprimed at 75% for 4 days (0.287 g). During 6th month, seeds bioprimed at 100 % for 6 days (1.613 g) recorded the highest fresh weight and the seeds bioprimed at 75 % for 4 days (0.293 g) recorded the lowest fresh weight.

The variation in dry weight biomass of seedlings bioprimed with *Pseudomonas fluorescens* at different durations and concentrations are presented in Table 32. At 30 DAT, the largest stem dry weight was shown in seedlings bioprimed at 100 % for 1 day (0.235 g) and the lowest value was shown at 50 % for 2 days (0.0244 g). During 6th month also seeds bioprimed at 100 % for 1 day (0.247 g) recorded the highest stem dry weight and the seeds bioprimed at 25 % for 2 days (0.057 g) recorded the lowest stem dry weight 50 % for 2 days (0.0867 g). The largest leaf dry weight at 30 DAT was shown in seedlings bioprimed at 50 % for 1 day (0.38 g) and the lowest dry weight was shown in seeds bioprimed at 100 % for 4 days (0.096 g). At 180 DAT, seeds bioprimed at 100 % for 6 days (0.51g) recorded the highest dry weight (leaf) and the seeds bioprimed at 75 % for 4 days (0.09 g) recorded the lowest dry weight. For the first month of observation the largest dry weight of roots was shown in in seedlings bioprimed at 100 % for 4 days (0.22 g) and the lowest in was bioprimed at 50% for 8 days (0.037g). During six month, the seedlings bioprimed at 50% for4 days (0.263 g) recorded the highest dry weight and the seeds bioprimed at 50% for 8 days (0.087 g) recorded the lowest value .The highest total plant dry weight was shown in seedlings bioprimed at 100% for 6 days (0.816 g) and the lowest dry weight was shown in seeds bioprimed at 75% for 4 days (0.191 g) at 30 DAT. During 6th month, the seedlings bioprimed at 100% for 1 day (0.793 g) recorded the highest dry weight and the seeds bioprimed at 75% for 4 days (0.197 g) recorded the lowest dry weight.

There was significant difference in dry weight of stem ($F=3.267$, $p < 0.01$) ,leaf ($F=12.974$, $p < 0.01$), root ($F=6.262$, $p < 0.01$) and total plant ($F=9.211$, $p < 0.01$) at 90 DAT and at 180 DAT fresh weight of leaf ($F=5.799$, $p < 0.01$), root ($F=3.835$, $p < 0.01$), dry weight of stem ($F=11.152$, $p < 0.01$) and total plant ($F=9.188$, $p < 0.01$) due to interactions between bioinoculant concentration and duration.

Table 31 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Pseudomonas fluorescens		Fresh weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT
25%	1	-	-	-	-	-	-	-	-
	2	0.357^{bcdef}	0.547^{cdef}	0.067^{ab}	0.110^{abc}	0.193^{abcdef}	0.283^{bcdefg}	0.543^{abcde}	0.933^{cdefg}
	3	-	-	-	-	-	-	-	-
	4	0.357^{bcdef}	0.547^{cdef}	0.047^{ab}	0.157^{abcd}	0.077^{ab}	0.167^{abc}	0.480^{abcd}	0.870^{cdef}
	6	0.500^{defg}	0.690^{efg}	0.060^{ab}	0.170^{abcd}	0.297^{bcdef}	0.387^{cdefg}	0.857^{bcdef}	1.247^{defgh}
	8	0.520^{efg}	0.710^{efg}	0.253^{bc}	0.100^{abc}	0.150^{abcd}	0.240^{abcde}	0.923^{def}	1.050^{cdefg}
50%	1	0.573^{fg}	0.763^{fg}	0.140^{abc}	0.157^{abcd}	0.400^{def}	0.490^{efg}	1.113^{ef}	1.410^{fgh}
	2	0.363^{bcdef}	0.553^{cdef}	0.037^{ab}	0.147^{abcd}	0.174^{abcde}	0.267^{abcdef}	0.577^{abcde}	0.967^{cdefg}
	3	0.343^{bcdef}	0.533^{cdef}	0.113^{abc}	0.223^{bcd}	0.220^{abcdef}	0.310^{bcdefg}	0.677^{bcdef}	1.067^{defg}
	4	0.463^{def}	0.653^{ef}	0.183^{abc}	0.197^{bcd}	0.457^{f}	0.547^{g}	1.103^{ef}	1.397^{efgh}
	6	0.267^{abcde}	0.457^{cde}	0.150^{abc}	0.173^{abcd}	0.223^{abcdef}	0.313^{bcdefg}	0.640^{bcdef}	0.943^{cdefg}
	8	0.387^{cdef}	0.577^{def}	0.190^{abc}	0.300^{de}	0.073^{ab}	0.163^{abc}	0.650^{bcdef}	1.040^{cdefg}
75%	1	0.413^{cdef}	0.603^{def}	0.107^{abc}	0.173^{abcd}	0.323^{bcdef}	0.413^{cdefg}	0.843^{bcdef}	1.190^{defgh}
	2	0.490^{defg}	0.680^{efg}	0.130^{abc}	0.240^{bcd}	0.263^{abcdef}	0.353^{bcdefg}	0.883^{cdef}	1.273^{defgh}
	3	0.170^{abc}	0.257^{abc}	0.070^{ab}	0.073^{ab}	0.087^{ab}	0.180^{abc}	0.327^{abc}	0.510^{abc}
	4	0.073^{ab}	0.147^{ab}	0.120^{abc}	0.160^{ab}	0.073^{ab}	0.087^{ab}	0.287^{ab}	0.293^{ab}
	6	0.367^{cdef}	0.557^{cdef}	0.077^{ab}	0.187^{bcd}	0.130^{abcd}	0.220^{abcde}	0.573^{abcde}	0.963^{cdefg}
	8	0.297^{bcdef}	0.487^{cdef}	0.040^{ab}	0.150^{abcd}	0.130^{abcd}	0.220^{abcde}	0.467^{abcd}	0.857^{cde}
100%	1	0.513^{efg}	0.703^{efg}	0.353^{c}	0.463^{e}	0.200^{abcdef}	0.290^{bcdefg}	1.067^{ef}	1.457^{gh}
	2	0.220^{abcd}	0.410^{bcde}	0.057^{ab}	0.167^{abcd}	0.077^{ab}	0.167^{abc}	0.353^{abcd}	0.743^{bcd}
	3	0.473^{def}	0.663^{efg}	0.147^{abc}	0.257^{cd}	0.107^{abc}	0.197^{abcd}	0.727^{bcdef}	1.117^{defgh}
	4	0.143^{abc}	0.333^{bcd}	0.120^{abc}	0.230^{bcd}	0.440^{ef}	0.530^{fg}	0.703^{bcdef}	1.093^{defgh}
	6	0.767^{g}	0.957^{g}	0.087^{ab}	0.197^{bcd}	0.370^{cdef}	0.460^{defg}	1.223^{f}	1.613^{h}
	8	0.357^{bcdef}	0.547^{cdef}	0.097^{ab}	0.097^{abc}	0.077^{ab}	0.167^{abc}	0.530^{abcde}	0.807^{bcd}
SEM		0.0537	0.0553	0.0466	0.0339	0.0507	0.0507	0.107	0.1

Main effects								
Concentration								
25%	0.289^{A}	0.416^{A}	0.059^{A}	0.089^{A}	0.119^{A}	0.179^{A}	0.467^{A}	0.683^{A}
50%	0.399^{B}	0.589^{B}	0.136^{B}	0.199^{C}	0.258^{C}	0.348^{C}	0.793^{B}	1.137^{C}
75%	0.302^{A}	0.455^{A}	0.091^{AB}	0.147^{B}	0.170^{AB}	0.246^{AB}	0.563^{A}	0.848^{B}
100%	0.412^{B}	0.602^{B}	0.143^{B}	0.234^{C}	0.212^{BC}	0.302^{BC}	0.767^{B}	1.138^{C}
SEM	0.0219	0.0226	0.019	0.0138	0.0207	0.0207	0.0438	0.0409
Duration								
1	0.375^{BC}	0.517^{BC}	0.150^{A}	0.198^{A}	0.231^{B}	0.298^{BC}	0.756^{BC}	1.014^{BC}
2	0.357^{AB}	0.547^{C}	0.054^{A}	0.166^{A}	0.177^{AB}	0.268^{ABC}	0.589^{AB}	0.979^{B}
3	0.247^{A}	0.363^{A}	0.083^{A}	0.138^{A}	0.103^{A}	0.172^{A}	0.432^{A}	0.673^{A}
4	0.259^{A}	0.420^{AB}	0.118^{A}	0.161^{A}	0.267^{B}	0.333^{C}	0.643^{ABC}	0.913^{B}
6	0.475^{C}	0.665^{D}	0.093^{A}	0.182^{A}	0.255^{B}	0.345^{C}	0.823^{C}	1.192^{C}
8	0.390^{BC}	0.580^{CD}	0.145^{A}	0.161^{A}	0.107^{A}	0.198^{AB}	0.642^{ABC}	0.938^{B}
SEM	0.0268	0.0276	0.0233	0.0169	0.0253	0.0254	0.0536	0.05
Values within the same column with similar superscripts are homogenous								

Table 32 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Pseudomonas fluorescens		Dry weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180DAT	30 DAT	180DAT

25%	1	-	-	-	-	-	-	-	-
	2	0.238^{bcdef}	0.250^{bcde}	0.041^{ab}	0.057^{abcd}	0.097^{abcdef}	0.140^{abcd}	0.362^{abcde}	0.447^{bcde}
	3	-	-	-	-	-	-	-	-
	4	0.238^{bcdef}	0.260^{bcde}	0.031^{ab}	0.103^{bcdef}	0.038^{ab}	0.097^{abc}	0.320^{abcd}	0.460^{bcde}
	6	0.333^{defg}	0.377^{bcde}	0.04^{ab}	0.086^{abcdef}	0.148^{bcdef}	0.173^{abcd}	0.571^{bcdef}	0.597^{cde}
	8	0.347^{efg}	0.360^{cde}	0.168^{bc}	0.173^{cdef}	0.075^{abcd}	0.107^{abc}	0.616^{def}	0.744^{bcde}
50%	1	0.382^{fg}	0.413^{e}	0.093^{abc}	0.112^{abcd}	0.200^{def}	0.247^{cd}	0.742^{ef}	0.763^{e}
	2	0.242^{bcdef}	0.290^{bcde}	0.024^{ab}	0.087^{abcdef}	0.088^{abcde}	0.147^{abcd}	0.384^{abcde}	0.523^{cde}
	3	0.229^{bcdef}	0.231^{bcde}	0.075^{abc}	0.123^{cdef}	0.110^{abcdef}	0.110^{abc}	0.451^{bcdef}	0.467^{bcde}
	4	0.180^{abcd}	0.309^{def}	0.122^{abc}	0.167^{abcde}	0.228^{f}	0.263^{cd}	0.526^{ef}	0.720^{cde}
	6	0.178^{abcde}	0.207^{abcde}	0.100^{abc}	0.113^{bcdef}	0.117^{abcdef}	0.150^{abcd}	0.427^{bcdef}	0.450^{bcde}
	8	0.258^{cdef}	0.277^{bcde}	0.126^{abc}	0.173^{fg}	0.037^{ab}	0.087^{abc}	0.433^{bcdef}	0.537^{cde}
75%	1	0.276^{cdef}	0.310^{bcde}	0.071^{abc}	0.087^{abcdef}	0.162^{bcdef}	0.203^{bcd}	0.562^{bcdef}	0.6^{de}
	2	0.327^{defg}	0.397^{bcde}	0.087^{abc}	0.163^{efg}	0.132^{abcdef}	0.163^{abcd}	0.589^{cdef}	0.623^{de}
	3	0.113^{abc}	0.117^{abc}	0.047^{ab}	0.060^{ab}	0.043^{ab}	0.103^{abc}	0.218^{abc}	0.233^{abc}
	4	0.049^{ab}	0.09^{ab}	0.080^{abc}	0.097^{abc}	0.047^{ab}	0.050^{ab}	0.191^{ab}	0.197^{ab}
	6	0.244^{cdef}	0.330^{de}	0.0511^{ab}	0.123^{cdef}	0.065^{abcd}	0.150^{abcd}	0.382^{abcde}	0.603^{de}
	8	0.198^{bcdef}	0.283^{bcde}	0.0267^{ab}	0.057^{abcd}	0.065^{abcd}	0.150^{abcd}	0.311^{abcd}	0.490^{bcde}
100%	1	0.342^{efg}	0.347^{de}	0.235^{c}	0.247^{g}	0.100^{abcdef}	0.140^{abcd}	0.711^{ef}	0.793^{e}
	2	0.147^{abcd}	0.247^{bcde}	0.0378^{ab}	0.093^{bcdef}	0.038^{ab}	0.103^{abc}	0.236^{abcd}	0.443^{bcde}
	3	0.316^{def}	0.327^{abcde}	0.098^{abc}	0.140^{defg}	0.053^{abc}	0.090^{abc}	0.484^{bcdef}	0.497^{bcde}
	4	0.096^{abc}	0.180^{abcd}	0.080^{abc}	0.110^{bcdef}	0.220^{ef}	0.307^{d}	0.469^{bcdef}	0.597^{de}
	6	0.237^{bcde}	0.511^{e}	0.058^{ab}	0.140^{defg}	0.185^{cdef}	0.170^{abcd}	0.816^{f}	0.910^{de}
	8	0.238^{bcdef}	0.297^{abcde}	0.064^{ab}	0.097^{abc}	0.038^{ab}	0.090^{abc}	0.353^{abcde}	0.547^{bcd}
SEM		0.0358	0.0407	0.0305	0.0166	0.0253	0.0355	0.0715	0.0588
Main effects									
Concentration									
25%		0.184^{A}	0.193^{A}	0.0469^{A}	0.049^{A}	0.0597^{A}	0.0861^{A}	0.311^{A}	0.320^{A}
50%		0.255^{B}	0.266^{B}	0.090^{AB}	0.100^{ABC}	0.1292^{C}	0.1672^{B}	0.529^{B}	0.533^{B}
75%		0.196^{AB}	0.201^{A}	0.060^{AB}	0.082^{B}	0.0856^{AB}	0.1367^{AB}	0.376^{A}	0.454^{B}

100%	0.234 ^{B}	0.275^{B}	0.0956^{B}	0.123^{C}	0.1058^{BC}	0.15^{B}	0.511^{B}	0.517^{B}
SEM	0.0146	0.0166	0.0125	0.00679	0.0103	0.0145	0.242	0.029
Duration								
1	0.250^{BC}	0.265^{C}	0.100^{A}	0.189^{AB}	0.115^{B}	0.148^{AB}	0.504^{BC}	0.506^{B}
2	0.238^{AB}	0.271^{C}	0.048^{A}	0.100^{AB}	0.087^{AB}	0.138^{AB}	0.393^{AB}	0.509^{B}
3	0.164^{A}	0.174^{A}	0.055^{A}	0.072^{A}	0.052^{A}	0.076^{A}	0.288^{A}	0.292^{A}
4	0.173^{A}	0.177^{AB}	0.078^{A}	0.082^{AB}	0.133^{B}	0.179^{B}	0.429^{ABC}	0.438^{B}
6	0.317^{C}	0.363^{BC}	0.062^{A}	0.111^{B}	0.128^{B}	0.161^{B}	0.549^{C}	0.564^{B}
8	0.260^{BC}	0.269^{C}	0.097^{A}	0.112^{AB}	0.537^{A}	0.108^{AB}	0.428^{ABC}	0.457^{B}
SEM	0.0179	0.0204	0.0153	0.00831	0.0127	0.0177	0.0357	0.0294
Values within the same column with similar superscripts are homogenous								

4.6.1.4. Plant Growth Analysis indices

The effect of biopriming on sandal seedlings with *Pseudomonas fluorescens* at different durations on plant growth analysis indices and vigour index are presented in Table 33.

Perusal of data indicated that at 30 DAT, the largest leaf area ratio was shown in seedlings bioprimed at 75% for 4 days (23.72 $cm^2 g^{-1}$) and the lowest was shown in seeds bioprimed at 100% for 1day (4.28 $cm^2 g^{-1}$). At 180 DAT, seeds bioprimed at 75% for 4 days recorded the highest LAR (66.5 $cm^2 g^{-1}$) and that at 75 % for 2 days (7.11 $cm^2 g^{-1}$) recorded the lowest value. While, the largest LWR was shown in seedlings bioprimed at 75 % for 8 days (0.580) and the lowest was shown in seeds bioprimed at 100% for 4 days (0.145) at 30 DAT. During 6^{th} month, the seeds bioprimed at 25% for 4 days (0.719) recorded the highest leaf weight ratio and the seeds bioprimed at 100 % for 4 days (0.193) recorded the lowest leaf weight ratio. The root: shoot ratio was highest in seedlings bioprimed at 100 % for 4 days (0.3977) and the lowest was shown in seeds bioprimed at 100% for 8 days (0.093) at 30DAT. At 180 DAT, the seeds bioprimed at 100 % for 4 days (1.058) recorded the highest root: shoot and the seeds bioprimed at 50% for 8 days (0.20) recorded the lowest root: shoot ratio. Concerning the vigour index, the highest VI was shown in seedlings bioprimed at 100% for 6 days (2184) and the lowest was shown in seeds bioprimed at 100% for 3days (159). During 6^{th} month also, the seedlings bioprimed at 100% for 6 days (3225) recorded the highest VI and the seeds bioprimed at 100 % for 3 days (364) recorded the lowest VI.

Statistical analysis revealed the significant difference in leaf weight ratio ($F=11.709$, $p < 0.01$), in root: shoot ratio ($F=5.846$, $p < 0.01$) and vigour index ($F=14.099$, $p < 0.01$), but leaf area ratio was not significant ($F=1.384$, $p =0.194$) at 30 DAT due to interaction between the bioinoculant concentration and duration. The interaction effect was also significant at 180 DAT in leaf area ratio ($F=7.169$, $p < 0.01$), leaf weight ratio ($F=9.539$, $p < 0.01$), in root: shoot ratio ($F=5.022$, $p < 0.01$) and vigour index ($F=29.726$, $p < 0.01$).

Table 33 Effect of biopriming with different concentrations of *Pseudomonas fluorescens* at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Pseudomonas fluorescens		Leaf Area Ratio (cm2 g-1)		Leaf Weight Ratio		Root : Shoot ratio		Vigor index	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-	-	-
	2	7.83^{a}	11.61^{a}	0.552^{bcd}	0.680^{d}	0.236^{bcd}	0.465^{abcd}	195^{abc}	314^{ab}
	3	-	-	-	-	-	-	-	-
	4	8.86^{a}	9.02^{a}	0.556^{bcd}	0.719^{d}	0.112^{abc}	0.265^{a}	877^{cdef}	1701^{ef}
	6	10.42^{a}	14.47^{a}	0.555^{bcd}	0599^{d}	0.233^{bcd}	0.481^{abcd}	245^{abc}	492^{abc}
	8	8.45^{a}	18.97^{a}	0.601^{d}	0.617^{d}	0.095^{abc}	0.312^{a}	470^{abcde}	769^{bcd}
50%	1	7.08^{a}	9.59^{a}	0.416^{c}	0.515^{cd}	0.241^{bcd}	0.496^{abcd}	1147^{ef}	1744^{ef}
	2	11.68^{a}	12.52^{a}	0.546^{bcd}	0.636^{d}	0.213^{bc}	0.418^{abc}	578^{abcde}	1147^{cde}
	3	4.90^{a}	16.29^{a}	0.492^{bcd}	0.551^{cd}	0.163^{abc}	0.330^{a}	509^{abcde}	859^{bcd}
	4	9.53^{a}	14.31^{a}	0.346^{bc}	0.422^{bcd}	0.270^{cd}	1.014^{cd}	357^{abc}	621^{abc}
	6	9.38^{a}	16.74^{a}	0.464^{bcd}	0.433^{bcd}	0.229^{bcd}	0.518^{abcd}	210^{abc}	491^{abc}
	8	12.35^{a}	18.62^{a}	0.512^{bcd}	0.593^{d}	0.067^{ab}	0.20^{a}	389^{abcd}	867^{bcd}
75%	1	8.51^{a}	10.68^{a}	0.412^{cd}	0.495^{bcd}	0.255^{cd}	0.527^{abcd}	1090^{def}	1951^{f}
	2	5.73^{a}	7.11^{a}	0.475^{bcd}	0.558^{cd}	0.193^{bc}	0.366^{ab}	322^{abc}	586^{abc}
	3	18.54^{a}	19.75^{a}	0.439^{bcd}	0.520^{cd}	0.162^{abc}	0.967^{bcd}	273^{abc}	691^{abc}
	4	23.72^{a}	66.5^{b}	0.259^{abc}	0.520^{bcd}	0.180^{abc}	0.399^{abc}	394^{abcd}	701^{abc}
	6	9.06^{a}	12.14^{a}	0.545^{bcd}	0.636^{d}	0.156^{abc}	0.342^{ab}	794^{bcde}	1673^{ef}
	8	17.21^{a}	19.65^{a}	0.580^{bcd}	0.658^{d}	0.178^{abc}	0.438^{abcd}	724^{bcde}	1433^{def}
100%	1	4.28^{a}	11.87^{a}	0.480^{bcd}	0.484^{bcd}	0.104^{abc}	0.251^{a}	536^{abcde}	1082^{cde}
	2	17.23^{a}	20.13^{a}	0.51^{bcd}	0.619^{d}	0.137^{abc}	0.314^{a}	439^{abcd}	764^{bcd}
	3	8.47^{a}	18.08^{a}	0.475^{bcd}	0.659^{d}	0.095^{abc}	0.265^{a}	159^{ab}	364^{ab}
	4	10.07^{a}	11.79^{a}	0.145^{b}	0.193^{ab}	0.400^{d}	1.058^{d}	557^{abcde}	873^{bcd}
	6	8.10^{a}	12.08^{a}	0.414^{bcd}	0.627^{d}	0.209^{bc}	0.459^{abcd}	2184^{g}	3225^{g}
	8	16.94^{a}	22.43^{a}	0.609^{cd}	0.678^{d}	0.0931^{abc}	0.393^{abc}	1545^{gh}	2143^{f}
SEM		5.02	4.95	0.0531	0.0531	0.0589	0.115	129	131
Main effects									

Concentration								
25%	5.93^{A}	8.51^{A}	0.380^{A}	0.436^{A}	0.113^{A}	0.254^{A}	298^{A}	546^{A}
50%	9.15^{AB}	11.34^{A}	0.496^{B}	0.525^{AB}	0.197^{B}	0.496^{B}	532^{B}	955^{B}
75%	13.79^{B}	21.17^{B}	0.512^{B}	0.521^{AB}	0.187^{B}	0.506^{B}	599^{B}	1173^{C}
100%	14.18^{A}	15.4^{AB}	0.471^{B}	0.543^{B}	0.173^{B}	0.456^{B}	903^{C}	1408^{D}
SEM	2.05	2.07	0.0217	0.024	0.0136	0.0471	52.7	53.5
Duration								
1	4.97^{A}	8.04^{A}	0.302^{AB}	0.373^{A}	0.15^{AB}	0.319^{A}	693^{CD}	1194^{CD}
2	13.12^{A}	12.85^{AB}	0.531^{CD}	0.623^{B}	0.195^{BC}	0.391^{A}	383^{AB}	703^{AB}
3	10.48^{A}	14.58^{A}	0.351^{A}	0.432^{A}	0.105^{A}	0.390^{A}	235^{A}	479^{A}
4	13.05^{A}	22.15^{B}	0.249^{BC}	0.398^{A}	0.240^{C}	0.684^{B}	546^{BC}	974^{BC}
6	9.24^{A}	13.86^{AB}	0.485^{BCD}	0.574^{B}	0.207^{BC}	0.450^{AB}	858^{D}	1470^{E}
8	13.74^{A}	15.67^{AB}	0.589^{D}	0.637^{B}	0.108^{A}	0.336^{A}	782^{CD}	1303^{DE}
SEM	2.51	2.47	0.0266	0.0295	0.0167	0.0577	64.6	65.5
Values within the same column with similar superscripts are homogenous								

4.6.2. Biopriming with *Trichoderma viride*

4.6.2.1. Seedling Growth

Impact of biopriming with *Trichoderma viride* at different concentrations and durations on the shoot parameters of sandal seedlings are presented in Table 34. In general biopriming positively influenced the seedling growth measured in terms of shoot height, collar diameter, leaf number, leaf area, root length, number of lateral roots and total seedling length. Statistical analysis revealed that the interaction effect of concentration and duration was significant in shoot height ($F=13.822$, $p < 0.01$), collar diameter ($F=5.202$, $p < 0.01$), leaf number ($F=14.878$, $p < 0.01$) and leaf area ($F=4.632$, $p < 0.01$) at 30 DAT and the interaction effect was also significant at 180 DAT in in shoot height ($F=33.484$, $p < 0.01$),collar diameter ($F=15.027$, $p < 0.01$), leaf number ($F=21.586$, $p < 0.01$) and leaf area ($F=12.943$, $p < 0.01$).

The highest shoot height was shown in seedlings bioprimed at 100% for 3 days (16.63 cm) and the lowest value was shown in seeds bioprimed at 50% for 6 days (5.5 cm) and 75% for 2 days (5.5 cm) at 30 DAT. At 180 DAT also seeds bioprimed at 100% for 3 days (24.5 cm) recorded the highest shoot height and the seeds bioprimed at 50% for 6 days and 75% for 2 days (13.4 cm) recorded the lowest seedling height. For the first month of observation, the largest collar diameter was shown in seedlings bioprimed at 100% for 1 day (1.873 mm) and the lowest was shown in seeds bioprimed at 75% for 6 days (0.433 mm). At 6^{th} month, seeds bioprimed at 50% for 2 days (3.34 mm) recorded the highest collar diameter and the lowest was recorded at 75 % for 6 days (1.62 mm). Seedlings bioprimed at 100% for 1 day also recorded the largest number of leaves (19.7) and the lowest was shown in seedlings bioprimed at 50% for 1 day and 75% for 2 days (11.7) at 30 DAT. At 180 DAT, seeds bioprimed at 100% for 1 day (23.7) recorded the highest leaf number and the seeds bioprimed at 50% for 1 day and 75% for 2 days (15.7) recorded the lowest leaf number. While, the largest leaf area was shown in seedlings bioprimed at 50% for 6 days (6.94 cm^2) and the lowest was shown in seeds bioprimed at 75% for 8 days (1.63 cm^2) at 30 DAT. At 180 DAT, the seeds bioprimed at 100% for 3 days (8.52 cm^2) and the seedlings bioprimed at 75% for 8 days (2.81 cm^2) recorded the lowest leaf area.

The variation in root parameters of the bioprimed seedlings is given in Table 35. For the first month of observation, the largest root length was shown in seedlings bioprimed at 50 % for 8 day (22.63 cm) and the lowest was shown in in seeds bioprimed at 25% for 4days (4.43cm) . During 6^{th} month, seeds bioprimed at 50% for 8 day (27.53 cm) recorded the highest root length also and the seeds bioprimed at 50 % for 4 days (9.17 cm) recorded the lowest root length. At 30 DAT, the largest root number was exhibited in seedlings bioprimed at100 % for 3 days, 75% for 1 day and 50% for 3 days (5.67) and the lowest number was shown in seeds bioprimed at 50% for 2 days and 100% for 2 days (2.67). Similarly, seeds bioprimed at 100 % for 3 days, 75% for 1 day (7.67) recorded the highest root number and the seeds bioprimed at 50% for 2 days and 100% for 2 days (4.67) recorded the lowest root number at 180 DAT. With regard to the total seedling length during first month, the tallest seedlings was observed in seedlings bioprimed at 100 % for 3 days (27.6 cm) and the shortest was seen in seeds bioprimed at 25 % for 2 days (11.8 cm) at 30 DAT. During 6^{th} month also, the seeds bioprimed at 100% for 3 days (40.4 cm) recorded the highest total seedling length and the seeds bioprimed at 75% for 2 days (22.8 cm) recorded the total seedling length (Table 35).

Statistical analysis indicated that the interaction effect of concentration and duration was significant in root length ($F=16.830$, $p< 0.01$), number of roots ($F=3.158$, $p < 0.01$) and total seedling length. ($F=18.372$, $p <$

0.01) at 30 DAT and the interaction effect was also significant at 180 DAT in root length ($F=30.196$, $p < 0.01$), number of roots ($F=5.336$, $p < 0.01$) and total seedling length ($F=39.744$, $p < 0.01$).

Table 34 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Trichoderma viride		Shoot Height (cm)		Collar Girth (mm)		Number of Leaves		Leaf Area (cm2)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	12.80^{bcd}	20.7^{bcd}	0.82^{abcde}	2.01^{bcdef}	16.00^{b}	20.00^{b}	3.28^{ab}	5.46^{bcde}
	2	6.07^{ab}	14.00^{b}	1.71^{cdef}	2.90^{cdefg}	18.30^{b}	22.30^{b}	3.65^{abcd}	4.36^{ab}
	3	-	-	-	-	-	-	-	-
	4	11.47^{bcd}	19.40^{bcd}	0.62^{abcd}	1.73^{bcd}	12.30^{b}	16.30^{b}	3.62^{abcd}	5.06^{ab}
	6	-	-	-	-	-	-	-	-
	8	8.23^{bc}	16.10^{bc}	0.99^{abcdef}	2.19^{bcdefg}	19.00^{b}	23.00^{b}	2.66^{ab}	7.56^{cde}
50%	1	10.53^{bcd}	18.40^{bcd}	1.82^{ef}	3.01^{efg}	11.70^{b}	15.70^{b}	2.65^{ab}	7.72^{de}
	2	7.30^{abc}	15.40^{bc}	2.15^{f}	3.34^{g}	16.70^{b}	20.70^{b}	1.92^{ab}	3.53^{abcd}
	3	6.43^{ab}	14.30^{b}	0.90^{abcde}	1.78^{bcde}	16.30^{b}	20.30^{b}	1.99^{ab}	2.95^{ab}
	4	8.73^{bc}	16.60^{bc}	1.41^{bcdef}	2.60^{bcdefg}	15.00^{b}	19.00^{b}	3.69^{ab}	7.76^{de}
	6	5.50^{ab}	13.40^{b}	1.74^{cdef}	2.93^{defg}	15.00^{b}	19.00^{b}	6.94^{b}	7.65^{de}
	8	5.93^{ab}	13.80^{b}	1.80^{def}	2.99^{defg}	18.00^{b}	22.00^{b}	2.78^{ab}	6.69^{bcde}
75%	1	10.07^{bcd}	18.00^{bcd}	0.63^{abcd}	1.82^{bcdef}	13.30^{b}	17.30^{b}	1.83^{ab}	3.90^{abcd}
	2	5.50^{ab}	13.40^{b}	0.47^{ab}	1.66^{bc}	11.70^{b}	15.70^{b}	5.63^{ab}	5.89^{bcd}
	3	-	-	-	-	-	-	-	-
	4	10.17^{bcd}	18.10^{bcd}	0.46^{ab}	1.65^{bc}	15.70^{b}	19.70^{b}	4.80^{ab}	7.79^{de}
	6	10.83^{bcd}	18.70^{bcd}	0.43^{ab}	1.62^{b}	17.30^{b}	21.30^{b}	3.72^{ab}	5.17^{bcde}
	8	12.53^{bcd}	20.40^{bcd}	0.57^{abc}	1.76^{bcde}	15.30^{b}	19.30^{b}	1.63^{ab}	2.81^{ab}
100%	1	8.90^{bc}	16.80^{bc}	1.87^{ef}	3.06^{fg}	19.70^{b}	23.70^{b}	4.00^{ab}	6.73^{de}
	2	14.03^{cd}	21.90^{cd}	1.83^{ef}	3.02^{efg}	15.70^{b}	19.70^{b}	5.96^{b}	7.87^{de}
	3	16.63^{d}	24.50^{d}	1.34^{bcdef}	2.53^{bcdefg}	19.00^{b}	23.00^{b}	4.71^{ab}	8.52^{e}
	4	11.33^{bcd}	19.20^{bcd}	0.62^{abcd}	1.81^{bcdef}	17.70^{b}	21.70^{b}	2.28^{ab}	6.30^{bcde}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
SEM		1.38	1.38	0.218	0.231	1.92	1.92	1.05	1.05
Main effects									

Concentration								
25%	6.43^{A}	11.7^{A}	0.692^{AB}	1.47^{A}	10.9^{A}	13.6^{A}	2.56^{A}	3.38^{A}
50%	7.41^{A}	15.3^{B}	1.634^{C}	2.77^{B}	15.4^{B}	19.4^{B}	3.33^{A}	5.75^{B}
75%	8.18^{A}	14.8^{B}	0.427^{A}	1.42^{A}	12.2^{A}	15.6^{A}	2.94^{A}	3.79^{A}
100%	8.48^{A}	13.8^{AB}	0.944^{B}	1.74^{A}	12^{A}	14.7^{A}	2.82^{A}	4.24^{A}
SEM	0.561	0.561	0.0891	0.0945	0.784	0.784	0.43	0.343
Duration								
1	10.57^{C}	18.48^{C}	1.286^{BC}	2.48^{C}	15.17^{B}	19.2^{B}	2.94^{ABC}	4.95^{CD}
2	8.22^{BC}	16.12^{C}	1.542^{C}	2.73^{C}	15.58^{B}	19.6^{B}	4.47^{C}	4.53^{BC}
3	5.77^{AB}	9.72^{AB}	0.560^{A}	1.08^{A}	8.83^{A}	10.8^{A}	1.67^{A}	2.87^{AB}
4	10.43^{C}	18.32^{C}	0.776^{A}	1.95^{B}	15.17^{B}	19.2^{B}	3.96^{BC}	6.37^{D}
6	4.08^{A}	8.03^{A}	0.542^{A}	1.14^{A}	8.08^{A}	10.1^{A}	2.66^{ABC}	2.75^{A}
8	6.67^{AB}	12.6^{B}	0.842^{AB}	1.73^{B}	13.08^{B}	16.1^{B}	1.77^{AB}	4.26^{ABC}
SEM	0.688	0.688	0.109	0.116	0.96	0.96	0.526	0.53
Values within the same column with similar superscripts are homogenous								

Table 35 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Trichoderma viride		Root Length (cm)		Number of Lateral Roots		Total Seedling Length (cm)	
Concentration	Duration (days)	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT
25%	1	14.27^{d}	19.27^{d}	5.33^{a}	7.33^{b}	27.20^{de}	40.00^{de}
	2	5.73^{abc}	10.63^{bc}	4.67^{a}	6.67^{b}	11.80^{ab}	24.60^{b}
	3	-	-	-	-	-	-

	4	4.43^{ab}	9.33^{b}	3.00^{a}	5.00^{ab}	15.90^{bcd}	28.70^{bcd}
	6	-	-	-	-	-	-
	8	9.30^{bcd}	14.20^{bcd}	3.33^{a}	5.33^{ab}	17.50^{bcde}	30.30^{bcde}
50%	1	5.47^{abc}	10.37^{bc}	3.67^{a}	5.67^{ab}	16.00^{bcd}	28.80^{bcd}
	2	7.63^{bcd}	12.53^{bcd}	2.67^{a}	4.67^{ab}	14.90^{bc}	27.70^{bc}
	3	8.10^{bcd}	13.00^{bcd}	5.67^{a}	7.67^{b}	14.50^{bc}	27.30^{bc}
	4	4.27^{ab}	9.17^{b}	5.33^{a}	7.33^{b}	13.00^{b}	25.80^{b}
	6	6.43^{abc}	11.33^{bc}	5.00^{a}	7.00^{b}	11.90^{ab}	24.70^{b}
	8	22.63^{e}	27.53^{e}	3.00^{a}	5.00^{ab}	28.60^{e}	41.40^{e}
75%	1	5.90^{abc}	10.80^{bc}	5.67^{a}	7.67^{b}	16.00^{bcd}	28.80^{bcd}
	2	4.50^{ab}	9.40^{b}	3.00^{a}	5.00^{ab}	10.00^{ab}	22.80^{b}
	3	-	-	-	-	-	-
	4	4.53^{ab}	9.43^{b}	4.00^{a}	6.00^{ab}	14.70^{bc}	27.50^{bc}
	6	5.17^{abc}	10.07^{bc}	5.00^{a}	7.00^{b}	16.00^{bcd}	28.80^{bcd}
	8	5.77^{abc}	10.67^{bc}	3.00^{a}	4.33^{ab}	18.30^{bcde}	31.10^{bcde}
100%	1	4.50^{ab}	9.40^{b}	4.33^{a}	5.67^{ab}	13.40^{b}	26.20^{b}
	2	11.63^{cd}	16.53^{cd}	2.67^{a}	4.67^{ab}	25.70^{cde}	38.50^{cde}
	3	10.93^{bcd}	15.83^{bcd}	5.67^{a}	7.67^{b}	27.60^{de}	40.40^{de}
	4	7.70^{bcd}	12.60^{bcd}	4.00^{a}	6.00^{ab}	19.00^{bcde}	31.80^{bcde}
	6	-	-	-	-	-	-
	8	-	-	-	-	-	-
SEM		0.788	1.24	0.0616	1.2	1.1	2.22
Main effects							
Concentration							
25%		5.64^{A}	8.91^{A}	2.77^{A}	4.06^{A}	12.1^{A}	20.6^{A}
50%		9.09^{B}	13.99^{B}	4.22^{A}	6.22^{B}	16.5^{B}	29.3^{B}
75%		4.31^{A}	8.39^{A}	3.44^{A}	5.00^{AB}	12.5^{A}	23.2^{A}
100%		5.79^{A}	9.06^{A}	2.78^{A}	4.00^{A}	14.3^{AB}	22.8^{A}
SEM		0.504	0.504	0.473	0.491	0.907	0.907
Duration							
1		7.56^{BC}	12.46^{BC}	4.75^{A}	6.58^{C}	18.13^{B}	30.9^{C}

2	7.38^{BC}	12.28^{BC}	3.25^{A}	5.25^{ABC}	15.60^{B}	28.4^{BC}
3	4.76^{A}	7.21^{A}	2.83^{A}	3.83^{AB}	10.53^{A}	16.9^{A}
4	5.23^{AB}	10.13^{B}	4.08^{A}	6.08^{BC}	15.66^{B}	28.5^{BC}
6	2.90^{A}	5.35^{A}	2.50^{A}	3.50^{A}	6.98^{A}	13.4^{A}
8	9.43^{C}	13.10^{C}	2.33^{A}	3.67^{AB}	16.10^{B}	25.7^{B}
SEM	0.618	0.618	0.579	0.601	1.11	1.11
Values within the same column with similar superscripts are homogenous						

4.6.2.2. Biomass production

Data pertaining to the fresh biomass accumulation of seedlings subjected to biopriming with *T.viride* at different concentration and duration are presented in Table 36. During initial observation the largest stem fresh weight was shown in seedlings bioprimed at 50% for 2 days (0.2 g) and lowest was shown in seeds bioprimed at 75% for 4 days (0.0733 g). The treatments recorded the highest fresh weight at 180 DAT was seeds bioprimed at 50% for 1 day (0.27 g) and the seeds bioprimed at 50% for 8 days (0.1533 g) recorded the lowest weight. Whereas, at 30 DAT the largest leaf fresh weight was shown in seedlings bioprimed at 75% for 8 days (0.953 g) and the lowest was in seeds bioprimed at 100% for 3days (0.080g). During 6th month, seeds bioprimed at 75% for 8 days (1.143 g) also recorded the highest leaf fresh weight and the seeds bioprimed at 100 % for 3 days (0.27 g) recorded the lowest value. The maximum root fresh weight at 30 DAT was shown in seedlings bioprimed at 50% for 3 days (0.5900 g) and the lowest was shown in seedlings bioprimed at 100 % for 3days (0.0867 g). Similarly, at 180 DAT seeds bioprimed at 50% for 3 days (0.680 g) recorded the highest fresh weight (root) and the seeds bioprimed at 50% for 8 days (0.08 g) recorded the lowest value. The largest fresh weight at 30 DAT was shown in seedlings bioprimed at 75% for 1 day (1.343 g) and the lowest was shown in seeds bioprimed at 50 % for 8 days (0.290 g). Similarly, at 180 DAT seedlings bioprimed at 75% for 1 day (1.663 g) recorded the highest fresh weight and the seedlings bioprimed at 100 % for 1 day (0.203 g) recorded the lowest fresh weight.

Analysis of variance revealed significant difference in fresh weight of leaf ($F=16.868$, $p < 0.01$), root ($F=12.849$, $p < 0.01$) and total fresh weight ($F=12.936$, $p < 0.01$) due to interaction between concentration and duration but fresh weight stem ($F=1.130$, $p =0.357$) was not significant at 30 DAT and the interaction was also significant at 180 days in in fresh weight of leaf ($F=23.717$, $p < 0.01$), stem ($F=2.242$, $p < 0.05$),root ($F=16.839$, $p < 0.01$) and total fresh weight ($F=17.161$, $p< 0.01$).

Variation in dry weight biomass of the sandal seedlings after biopriming with *Trichoderma viride* at different duration and concentration are presented in Table 37. At 30 DAT, the highest stem dry weight was shown in the seedlings bioprimed at 50% for 2 days (0.1333 g) and the lowest stem dry weight was shown in seeds bioprimed at 75% for 6 days (0.0433 g). Similarly, seeds bioprimed at 25% for 8 days (0.1533 g) recorded the highest while those at 100 % for 3 days (0.0533 g) recorded the lowest stem dry weight. With regard to the leaf dry weight, at 30 DAT the largest leaf dry weight was shown in seedlings bioprimed at 50% for 2 days (0.5889 g) and the lowest value was shown in seeds bioprimed at 100 % for 3 days (0.0533 g). At 180 DAT also, seedlings bioprimed at 50% for 2 days (0.6167 g) and 100% for 1 day (0.0933 g) recorded the highest recorded the highest and the lowest values. For the first month of observation, the largest root dry weight was recorded in seedlings bioprimed at 50% for 3 days (0.2950 g) and the lowest dry weight was shown in seeds bioprimed at 100% for 1days (0.0217 g). Subsequently, during 6th month, seeds bioprimed at 50% for 3 days (0.37 g) recorded the highest dry weight (roots) and the seeds bioprimed at 50 % for 8 days (0.05 g) recorded the lowest value. During the initial observation, the largest dry weight biomass was recorded in seedlings bioprimed at 75% for 1 day (0.896 g) and the lowest dry weight was shown in seeds bioprimed at 100% for 1day (0.136 g). During 6th month, seeds bioprimed at 75% for 2days (0.91 g) recorded the highest dry weight and the seeds bioprimed at 100 % for 1 day (0.180 g) recorded the lowest dry weight . Analysis of variance revealed significant difference in dry weight of leaf ($F=17.263$, $p < 0.01$), root ($F=13.284$, $p < 0.01$) and the total dry

weight ($F=12.874$, $p < 0.01$) due to interaction between concentration and duration but the dry weight stem was not significant ($F=1.102$, $p =0.380$) at 30 DAT. The interaction was also significant at 180 days in dry weight of stem ($F=1.954$, $p < 0.01$), leaf ($F=8.137$, $p < 0.01$) and root ($F=9.522$, $p < 0.01$) and total fresh weight ($F=10.026$, $p < 0.01$).

Table 36 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Trichoderma viride		Fresh weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	0.407^{bcdef}	0.597^{bcdef}	0.087^{a}	0.197^{ab}	0.130^{abcd}	0.220^{abcde}	0.623^{bcdef}	1.013^{bcdefg}
	2	0.737^{fghi}	0.927^{fghi}	0.083^{a}	0.193^{ab}	0.377^{de}	0.467^{ef}	1.197^{efgh}	1.587^{fgh}
	3	-	-	-	-	-	-	-	-
	4	0.110^{abc}	0.267^{ab}	0.147^{a}	0.167^{ab}	0.100^{abc}	0.143^{abc}	0.357^{abc}	0.577^{abc}
	6	-	-	-	-	-	-	-	-
	8	0.250^{abcd}	0.440^{bcd}	0.090^{a}	0.200^{ab}	0.060^{ab}	0.150^{abc}	0.400^{abc}	0.790^{bcd}
50%	1	0.360^{bcde}	0.550^{bcde}	0.160^{a}	0.270^{b}	0.097^{abc}	0.187^{abc}	0.617^{abcde}	1.007^{bcdefg}
	2	0.883^{hi}	1.073^{hi}	0.200^{a}	0.210^{ab}	0.163^{abcd}	0.253^{bcde}	1.247^{gh}	1.537^{efgh}
	3	0.623^{efghi}	0.813^{efghi}	0.107^{a}	0.217^{ab}	0.590^{e}	0.680^{f}	1.320^{h}	1.710^{h}
	4	0.400^{bcdef}	0.590^{bcdef}	0.087^{a}	0.197^{ab}	0.167^{abcd}	0.257^{bcde}	0.653^{bcdefg}	1.043^{bcdefg}
	6	0.443^{cdef}	0.633^{cdef}	0.110^{a}	0.220^{ab}	0.350^{cde}	0.440^{def}	0.903^{cdefgh}	1.293^{defgh}
	8	0.133^{abc}	0.323^{abc}	0.113^{a}	0.153^{ab}	0.043^{ab}	0.080^{ab}	0.290^{abc}	0.557^{abc}
75%	1	0.800^{ghi}	0.990^{ghia}	0.167^{a}	0.207^{ab}	0.377^{de}	0.467^{ef}	1.343^{h}	1.663^{gh}
	2	0.483^{defg}	0.673^{defg}	0.133^{a}	0.243^{b}	0.580^{e}	0.670^{f}	1.197^{efgh}	1.587^{fgh}
	3	-	-	-	-	-	-	-	-
	4	0.300^{abcde}	0.490^{bcde}	0.073^{a}	0.183^{ab}	0.137^{abcd}	0.227^{abcde}	0.510^{abcd}	0.9^{bcde}
	6	0.553^{defgh}	0.743^{defgh}	0.190^{a}	0.223^{ab}	0.257^{bcd}	0.347^{cde}	1.100^{defgh}	1.213^{cdefgh}
	8	0.953^{i}	1.143^{i}	0.160^{a}	0.193^{ab}	0.130^{abcd}	0.220^{abcde}	1.243^{fgh}	1.497^{efgh}
100%	1	0.133^{abc}	0.323^{abc}	0.143^{a}	0.163^{ab}	0.037^{ab}	0.120^{abc}	0.203^{ab}	0.543^{ab}
	2	0.400^{bcdef}	0.590^{bcdef}	0.097^{a}	0.163^{ab}	0.107^{abc}	0.197^{abcd}	0.603^{abcde}	0.950^{bcdef}
	3	0.080^{ab}	0.270^{ab}	0.833^{a}	0.867^{ab}	0.087^{ab}	0.177^{abc}	0.250^{ab}	0.533^{ab}
	4	0.447^{cdef}	0.637^{cdef}	0.0867^{a}	0.197^{ab}	0.217^{abcd}	0.307^{bcde}	$0.750^{bcdefgh}$	$1.140^{bcdefgh}$
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
SEM		0.0635	0.0629	0.0632	0.0424	0.0469	0.0463	0.114	0.121

Main effects								
Concentration								
25%	0.251^{A}	0.372^{A}	0.068^{A}	0.126^{A}	0.111^{A}	0.163^{A}	0.429^{A}	0.661^{A}
50%	0.474^{B}	0.664^{B}	0.129^{A}	0.211^{B}	0.235^{B}	0.316^{B}	0.838^{B}	1.191^{B}
75%	0.515^{B}	0.673^{B}	0.137^{A}	0.148^{AB}	0.247^{B}	0.322^{B}	0.899^{B}	1.143^{B}
100%	0.177^{A}	0.303^{A}	0.052^{A}	0.091^{A}	0.074^{A}	0.133^{A}	0.301^{A}	0.528^{A}
SEM	0.0259	0.0257	0.0258^{A}	0.0212	0.0192	0.0189	0.0466	0.0493
Duration								
1	0.425^{C}	0.615^{C}	0.114^{A}	0.193^{B}	0.160^{B}	0.248^{B}	0.697^{B}	1.057^{C}
2	0.626^{D}	0.816^{D}	0.128^{A}	0.203^{B}	0.307^{C}	0.397^{C}	1.061^{C}	1.415^{D}
3	0.176^{A}	0.271^{A}	0.048^{A}	0.076^{A}	0.169^{B}	0.214^{B}	0.393^{A}	0.561^{A}
4	0.314^{BC}	0.496^{BC}	0.098^{A}	0.186^{B}	0.155^{AB}	0.233^{B}	0.568^{AB}	0.915^{BC}
6	0.249^{AB}	0.344^{A}	0.100^{A}	0.110^{A}	0.152^{AB}	0.197^{AB}	0.501^{AB}	0.627^{A}
8	0.334^{BC}	0.477^{B}	0.091^{A}	0.122^{AB}	0.0583^{A}	0.112^{A}	0.483^{AB}	0.711^{AB}
SEM	0.0318	0.0314	0.0316	0.0212	0.0235	0.0232	0.0571	0.0604
Values within the same column with similar superscripts are homogenous								

Table 37 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Trichoderma viride		Dry weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT

25%	1	0.261^{bcdef}	0.263^{abcd}	0.058^{a}	0.110^{ab}	0.065^{abcd}	0.140^{abc}	0.416^{bcdef}	0.513^{bcde}
	2	0.491^{fghia}	0.510^{cde}	0.056^{a}	0.100^{ab}	0.128^{de}	0.140^{abc}	0.798^{efgh}	0.833^{cdef}
	3	-	-	-	-	-	-	-	-
	4	0.073^{abc}	0.143^{ab}	0.098^{a}	0.103^{ab}	0.050^{abc}	0.093	0.238^{abc}	0.340^{abc}
	6	-	-	-	-	-	-	-	-
	8	0.167^{abcd}	0.193^{abc}	0.060^{a}	0.153^{b}	0.030^{ab}	0.070^{abc}	0.267^{abc}	0.417^{abcd}
50%	1	0.210^{bcde}	0.223^{abc}	0.107^{a}	0.140^{ab}	0.048^{abc}	0.127^{abc}	0.411^{abcde}	0.480^{bcde}
	2	0.589^{hia}	0.617^{e}	0.133^{a}	0.143^{ab}	0.082^{abcd}	0.120^{abc}	0.831^{gh}	0.840^{def}
	3	0.416^{efghia}	0.460^{cde}	0.071^{a}	0.130^{ab}	0.295^{e}	0.370^{d}	0.880^{h}	0.960^{f}
	4	0.267^{bcdef}	0.380^{bcde}	0.058^{a}	0.130^{ab}	0.083^{abcd}	0.160^{bc}	0.436^{bcdefg}	0.670^{cdef}
	6	0.296^{cdef}	0.300^{bcd}	0.073^{a}	0.090^{ab}	0.175^{cde}	0.178^{bc}	0.602^{cdefgh}	0.643^{cdef}
	8	0.089^{abc}	0.217^{abc}	0.076^{a}	0.103^{ab}	0.022^{ab}	0.050^{ab}	0.193^{abc}	0.370^{abc}
75%	1	0.533^{ghia}	0.540^{de}	0.111^{a}	0.120^{ab}	0.188^{de}	0.207^{c}	0.896^{h}	0.897^{ef}
	2	0.322^{defg}	0.410^{cde}	0.089^{a}	0.090^{ab}	0.190^{de}	0.193^{bc}	0.798^{efgh}	0.910^{ef}
	3	-	-	-	-	-	-	-	-
	4	0.200^{abcde}	0.253^{abcd}	0.049^{a}	0.103^{ab}	0.068^{abcd}	0.120^{abc}	0.340^{abcd}	0.477^{bcde}
	6	0.369^{defgh}	0.457^{cde}	0.043^{a}	0.067^{ab}	0.128^{bcd}	0.187^{bc}	0.733^{defgh}	0.740^{cdef}
	8	0.397^{def}	0.400^{cde}	0.057^{a}	0.060^{ab}	0.065^{abcd}	0.097^{abc}	0.829^{fgh}	0.830^{ef}
100%	1	0.089^{abc}	0.093^{a}	0.029^{a}	0.063^{ab}	0.018^{ab}	0.053^{ab}	0.136^{ab}	0.180^{ab}
	2	0.267^{bcdef}	0.287^{abcd}	0.064^{a}	0.097^{ab}	0.053^{abc}	0.107^{abc}	0.402^{abcde}	0.490^{bcde}
	3	0.053^{ab}	0.117^{ab}	0.050^{a}	0.053^{ab}	0.043^{ab}	0.127^{abc}	0.167^{ab}	0.297^{abc}
	4	0.298^{cdef}	0.300^{abcd}	0.058^{a}	0.080^{ab}	0.108^{abcd}	0.170^{bc}	0.500^{bcdefgh}	0.510^{bcde}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
SEM		0.0423	0.05	0.0421	0.0421	0.0235	0.0279	0.0761	0.0787
Main effects									
Concentration									
25%		0.167^{A}	0.169^{A}	0.045^{A}	0.078^{AB}	0.0556^{A}	0.0739^{A}	0.286^{A}	0.317^{A}
50%		0.316^{B}	0.348^{B}	0.086^{A}	0.112^{B}	0.1175^{B}	0.1667^{B}	0.559^{B}	0.631^{C}
75%		0.343^{B}	0.381^{B}	0.062^{A}	0.070^{A}	0.1233^{B}	0.1339^{B}	0.599^{B}	0.642^{B}
100%		0.118^{A}	0.125^{A}	0.034^{A}	0.049^{A}	0.0372^{A}	0.0761^{A}	0.201^{A}	0.230^{A}

SEM	0.0173	0.0208	0.0172	0.0108	0.00958	0.0114	0.0311	0.0321
Duration								
1	0.283^{C}	0.290^{BC}	0.076^{A}	0.103^{C}	0.080^{B}	0.132^{B}	0.464^{B}	0.506^{C}
2	0.360^{C}	0.417^{D}	0.086^{A}	0.098^{BC}	0.153^{C}	0.140^{B}	0.607^{C}	0.698^{C}
3	0.114^{A}	0.117^{A}	0.032^{A}	0.046^{AB}	0.085^{B}	0.124^{B}	0.262^{A}	0.314^{AB}
4	0.235^{AB}	0.290^{BC}	0.066^{A}	0.104^{C}	0.078^{AB}	0.136^{B}	0.378^{AB}	0.475^{BC}
6	0.164^{AB}	0.166^{AB}	0.037^{A}	0.040^{A}	0.076^{AB}	0.090^{AB}	0.334^{AB}	0.393^{AB}
8	0.171^{AB}	0.223^{BC}	0.061^{A}	0.079^{ABC}	0.029^{A}	0.054^{A}	0.322^{AB}	0.327^{A}
SEM	0.0212	0.028	0.0211	0.0233	0.0117	0.014	0.0381	0.0393
Values within the same column with similar superscripts are homogenous								

4.6.2.3. Plant Growth analysis indices and vigour index

The effect biopriming with *Trichoderma viride* at different concentrations and durations on the leaf area ratio, leaf weight ratio and root: shoot ratio and vigour index of sandal seedlings is depicted in Table 38.With regard to LAR, for the first month of observation the largest ratio was shown in seedlings bioprimed at 100% for 3 days (21.06 $cm^2 g^{-1}$) and the lowest was in seedlings bioprimed at 75% for 8 days (1.95 $cm^2 g^{-1}$). Similarly, during 6^{th} month, seedlings bioprimed at 100 % for 3 days (29.36 $cm^2 g^{-1}$) recorded the highest LAR and the seeds bioprimed at 50% for 3 days (3.19 $cm^2 g^{-1}$) recorded the lowest leaf area ratio. At 30 DAT, the largest leaf weight ratio (0.710) and the lowest (0.255) LWR was shown in seedlings bioprimed at 50% for 2 days and 25% for 4 days, respectively. The seedlings bioprimed at 50% for 2 days (0.738) recorded the highest LWR the seeds bioprimed at 100 % for 4 days (0.390) recorded the lowest LWR at 180 DAT. The largest root: shoot at 30 DAT was shown in seedlings bioprimed at 75% for 2 days (0.330) and the lowest was at 75% for 8 days (0.0689). Seeds bioprimed at 75% for 2 days (0.832) recorded the highest root: shoot and the seeds bioprimed at 75% for 8 days (0.288) recorded the lowest root: shoot at 180 DAT. The largest VI at 30DAT was shown in seedlings bioprimed at 100% for 3 days (2274.2) and the lowest was in seeds bioprimed at 75 % for 2 days (89.4). During 6^{th} month, seedlings bioprimed at 100% for 3 days (3332) recorded the highest VI and the seeds bioprimed at 75% for 2 days (200) recorded the lowest VI. Statistical analysis revealed significant difference in leaf area ratio ($F=2.132$, $p < 0.05$), leaf weight ratio ($F=10.201$, $p < 0.01$), root: shoot ratio ($F=6.009$, $p < 0.01$) and vigour index ($F=31.010$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT. The interaction was also significant at 180 days in leaf area ratio ($F=7.920$, $p < 0.01$), leaf weight ratio ($F=19.006$, $p < 0.01$), root: shoot ratio ($F=10.612$, $p < 0.01$) and vigour index ($F=72.173$, $p < 0.01$).

Table 38 Effect of biopriming with different concentrations of *Trichoderma viride* at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Trichoderma viride		Leaf Area Ratio (cm2 g-1)		Leaf Weight Ratio		Root : Shoot ratio		Vigor index	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	7.83^{a}	11.52^{ab}	0.511^{cd}	0.648^{bcd}	0.143^{abcd}	0.391^{abcdef}	1271.8^{f}	1869^{iaib}
	2	5.83^{a}	6.54^{ab}	0.578^{bcd}	0.611^{bcd}	0.226^{abcd}	0.370^{abcde}	649.2^{cde}	1357^{ghia}
	3	-	-	-	-	-	-	-	-
	4	6.57^{a}	12.48^{ab}	0.255^{ab}	0.441^{bc}	0.136^{abcd}	0.388^{abcdef}	295.1^{abc}	534^{bcd}
	6	-	-	-	-	-	-	-	-
	8	11.42^{a}	19.81^{bc}	0.421^{bcd}	0.452^{bc}	0.091^{abc}	0.204^{abc}	510.9^{abcde}	886^{cdefg}
50%	1	6.53^{a}	16.33^{abc}	0.387^{bcd}	0.444^{bc}	0.098^{abc}	0.360^{abcde}	682.4^{cde}	1229^{fgh}
	2	2.49^{a}	4.37^{ab}	0.710^{d}	0.738^{d}	0.086^{abc}	0.174^{ab}	537.6^{bcde}	998^{defg}
	3	1.98^{a}	3.19^{ab}	0.482^{bcd}	0.490^{bcd}	0.304^{cd}	0.638^{cdef}	588.6^{bcde}	1109^{efgh}
	4	7.74^{a}	13.31^{abc}	0.509^{bcd}	0.553^{bcd}	0.174^{abcd}	0.339^{abcde}	944.4^{ef}	1875^{i}
	6	13.34^{a}	15.07^{abc}	0.401^{bcd}	0.427^{bc}	0.257^{bcd}	0.593^{bcdef}	440^{abcde}	909^{cdefg}
	8	15.17^{a}	19.09^{bc}	0.396^{bcd}	0.595^{bcd}	0.181^{abcd}	0.191^{ab}	285.7^{abc}	414^{abc}
75%	1	1.96^{a}	4.87^{ab}	0.598^{bcd}	0.643^{cd}	0.187^{abcd}	0.332^{abcde}	500.1^{abcde}	901^{cdefg}
	2	6.07^{a}	7.17^{ab}	0.416^{bcd}	0.436^{bcd}	0.330^{d}	0.832^{f}	89.4^{ab}	200^{ab}
	3	-	-	-	-	-	-	-	-
	4	14.57^{a}	16.54^{abc}	0.567^{bcd}	0.620^{cd}	0.175^{abcd}	0.342^{abcde}	339.4^{abc}	638^{bcde}
	6	5.71^{a}	7.92^{ab}	0.535^{bcd}	0.633^{cd}	0.169^{abcd}	0.370^{abcde}	398.3^{abcd}	714^{bcdef}
	8	1.95^{a}	6.79^{ab}	0.567^{bcd}	0.642^{cd}	0.069^{ab}	0.288^{abcd}	541.7^{bcde}	917^{cdefg}
100%	1	10.92^{a}	15.38^{abc}	0.667^{d}	0.677^{cd}	0.103^{abcd}	0.438^{abcdef}	627.2^{cde}	1225^{fgh}
	2	15.49^{a}	17.87^{bc}	0.556^{d}	0.591^{bcd}	0.120^{abcd}	0.300^{abcd}	718.7^{cde}	1077^{efgh}
	3	21.06^{a}	29.36^{c}	0.267^{abc}	0.398^{bc}	0.255^{bcd}	0.765^{ef}	2274.2^{g}	3332^{i}
	4	5.01^{a}	15.46^{abc}	0.304^{abc}	0.390^{bc}	0.192^{abcd}	0.716^{def}	913.6^{def}	1528^{hi}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
SEM		9.74	4.06	0.0702	0.048	0.0424	0.0816	94.6	94.6
Main effects									

Concentration								
25%	7.28^{A}	8.39^{AB}	0.357^{A}	0.490^{BC}	0.0994^{A}	0.226^{A}	454^{AB}	774^{B}
50%	11.21^{A}	11.89^{AB}	0.548^{B}	0.561^{C}	0.1832^{B}	0.376^{B}	580^{B}	1089^{C}
75%	5.38^{A}	7.22^{A}	0.180^{A}	0.222^{A}	0.1551^{AB}	0.361^{B}	311^{A}	562^{A}
100%	12.41^{A}	13.01^{B}	0.366^{A}	0.476^{BC}	0.1117^{A}	0.370^{B}	756^{C}	1194^{C}
SEM	3.98	2.25	0.0287	0.0196	0.0173	0.0333	38.6	38.6
Duration								
1	11.81^{A}	12.02^{AB}	0.325^{A}	0.490^{BC}	0.1326^{AB}	0.380^{BC}	770^{D}	1306^{C}
2	7.97^{A}	8.99^{AB}	0.400^{B}	0.561^{C}	0.1904^{B}	0.419^{C}	449^{BC}	908^{B}
3	7.76^{A}	8.14	0.187^{A}	0.222^{A}	0.1398^{AB}	0.351^{BC}	716^{D}	1110^{C}
4	11.97^{A}	14.45^{B}	0.409^{B}	0.476^{BC}	0.1692^{AB}	0.446^{C}	623^{CD}	1144^{C}
6	4.76^{A}	5.75^{A}	0.259^{A}	0.265^{A}	0.1067^{AB}	0.241^{AB}	210^{A}	406^{A}
8	9.14^{A}	11.42^{AB}	0.446^{B}	0.452^{B}	0.0854^{A}	0.161^{A}	335^{AB}	554^{A}
SEM	4.87	2.53	0.0351	0.024	0.0212	0.0408	47.3	47.3
Values within the same column with similar superscripts are homogenous								

4.6.3. Biopriming with PGPR II

4.6.3.1. Seedling Growth

Impact of biopriming with PGPRII at different duration and concentration on the shoot characteristics of sandal seedlings are presented in Table 39. The tallest seedlings were recorded in biopriming at 100 % for 6 days (17.6 cm) and the shortest was shown in seeds bioprimed at 25 % for 2 days (3.37 cm) at 30 DAT. At 180 DAT also the seeds bioprimed at 100 % for 6 days recorded the highest seedling height (25.5 cm) and the seeds bioprimed at 100 % for 3 days recorded the lowest seedling height (6.1 cm).While, the largest collar diameter was shown in seedlings bioprimed at 50% for 3 days (2.25 mm) and the lowest was in that at 25% for 6 days (0.27 mm). At 180 DAT also, seedlings bioprimed at 50% for 3 days (3.44 mm) recorded the highest collar diameter and lowest was at 25% for 6 days (1.46 mm).For the first month of observation the largest leaf number was recorded in seedlings bioprimed at100 % for 2 days (18.01) and the lowest was at 50% for1 day (10.31). During 6^{th} month, seeds bioprimed at 100 % for 2 days (22) and at 50 % for 1 day (14.3) recorded the highest and lowest values. With regard to leaf area, at 30 DAT the largest leaf area was shown in seedlings bioprimed at 75 % for 1 day (7.13 cm^2) and the lowest was shown in seeds bioprimed at 100% for 2days (2.18 cm^2). But at 180 DAT, seedlings bioprimed at 50% for 4 days (7.75 cm^2) recorded the highest leaf area and the seeds bioprimed at100 % for 2 days (2.83 cm^2) recorded the lowest value. The difference in shoot height ($F=13.091$, $p < 0.01$), collar diameter ($F=10.746$, $p < 0.01$), leaf number ($F=16.922$, $p < 0.01$) and leaf area ($F=3.485$, $p < 0.01$) was significant due to interaction effect of concentration and duration of bioinoculant at 30 DAT. The interaction was also significant at 180 days in seedling height ($F=30.197$, $p < 0.01$), collar diameter ($F=31.041$, $p < 0.01$), leaf number ($F=27.324$, $p < 0.01$) and ($F=5.548$, $p < 0.01$).

Impact of biopriming with PGPR II at different concentration and duration on the root characteristics of sandal seedlings are presented in Table 40. During first month of observation the largest root length was observed in seedlings bioprimed at 50% for 3 days (14.2 cm) and the lowest was in seedlings bioprimed at 50 % for 1day (1.67 cm). During 6^{th} month also, the seeds bioprimed at 50% for 3 days (19.1 cm) recorded the highest root length but the seeds bioprimed at 50% for 4 days (4.93 cm) recorded the lowest. At 30 DAT, the largest root number was shown in seedlings bioprimed at 50% for 3 days (10.33) and the lowest was at 100% for 4 days and 50% for 2 days (2.67). At180 DAT also the seedlings bioprimed at 50 % for 3 days (11.33) recorded the highest root number and the seedlings bioprimed at 100% concentration for 4 days and 50% for 2 days (4.00) recorded the lowest root number.

During the first month of observation the largest total seedling length was shown in seedlings bioprimed at 50% for 6 days (23 cm) and the lowest was in those at 50% for 1day (5.23 cm).Similar to 30 DAT, seeds bioprimed at 50% for 6 days (35.8 cm) recorded the highest total seedling length and the lowest was for seeds bioprimed at 50 % for 2 days (16.5 cm) during 6^{th} month of observation. The difference in root length ($F=17.159$, $p< 0.01$), number of roots ($F=6.287$, $p < 0.01$) and total seedling length ($F=20.975$, $p < 0.01$) was significant due to interaction effect of concentration and duration of bioinoculant at 30 DAT. The interaction effect was also significant at 180 days in root length ($F=60.503$, $p < 0.01$), number of roots ($F=8.741$, $p < 0.01$) and total seedling length ($F=43.796$, $p < 0.01$).

Table 39 Effect of biopriming with different concentrations of PGPR II at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

PGPR 2		Shoot Height (cm)		Collar Girth (mm)		Number of Leaves		Leaf Area (cm2)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-	-	-
	2	3.37^{ab}	10.50^{b}	0.91^{abcde}	2.11^{bcde}	12.70^{bc}	16.70^{bc}	5.61^{ab}	7.32^{bc}
	3	7.43^{abcd}	15.30^{bcd}	0.79^{abcd}	1.98^{bcd}	16.30^{bc}	20.30^{bc}	3.90^{ab}	4.65^{abc}
	4	11.80^{bcde}	19.70^{cde}	1.38^{cdefg}	2.57^{cdefg}	12.30^{b}	16.30^{b}	1.61^{ab}	6.56^{bc}
	6	13.10^{de}	21.00^{de}	0.27^{ab}	1.46^{b}	14.01^{bc}	18.00^{bc}	2.48^{ab}	4.4^{abc}
	8	-	-	-	-	-	-	-	-
50%	1	3.57^{abc}	11.50^{bc}	0.40^{ab}	1.59^{b}	10.31^{b}	14.30^{b}	4.53^{ab}	10.76^{c}
	2	3.43^{ab}	11.30^{bc}	0.79^{abcd}	1.98^{bcd}	12.71^{bc}	16.70^{bc}	3.45^{ab}	7.44^{bc}
	3	14.97^{de}	22.90^{de}	2.25^{g}	3.44^{g}	15.31^{bc}	19.30^{bc}	5.88^{ab}	5.93^{abc}
	4	14.17^{de}	22.10^{de}	0.71^{abc}	1.90^{bc}	16.71^{bc}	20.70^{bc}	3.08^{ab}	7.75^{bc}
	6	14.93^{de}	22.80^{de}	1.21^{bcdef}	2.41^{bcdef}	13.31^{bc}	17.30^{bc}	6.04^{ab}	7.33^{bc}
	8	-	-	-	-	-	-	-	-
75%	1	4.30^{abc}	12.20^{bc}	0.56^{abc}	1.76^{bc}	15.01^{bc}	19.00^{bc}	7.18^{b}	6.44^{abc}
	2	11.47^{bcde}	19.40^{cde}	1.80^{efg}	2.99^{efg}	17.01^{bc}	21.00^{bc}	6.86^{b}	6.61^{bc}
	3	12.07^{cde}	20.00^{cde}	1.89^{fg}	3.08^{fg}	20.71^{c}	24.70^{c}	3.80^{ab}	7.09^{bc}
	4	12.07^{cde}	20.00^{cde}	0.62^{abc}	1.82^{bc}	12.71^{bc}	16.70^{bc}	4.88^{ab}	5.46^{abc}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
100%	1	8.17^{abcd}	16.10^{bcd}	0.57^{abc}	1.76^{bc}	12.71^{bc}	16.70^{bc}	6.16^{ab}	3.05^{ab}
	2	8.77^{bcd}	16.70^{bcd}	1.68^{defg}	2.87^{defg}	18.01^{bc}	22.00^{bc}	2.18^{ab}	2.83^{ab}
	3	8.17^{abcd}	6.10^{bcd}	0.85^{abcde}	2.04^{bcde}	13.70^{bc}	17.70^{bc}	3.17^{ab}	7.56^{bc}
	4	-	-	-	-	-	-	-	-
	6	17.60^{e}	25.50^{e}	0.62^{abc}	1.81^{bc}	11.70^{b}	15.70^{b}	6.16^{ab}	7.53^{bc}
	8	11.37^{bcde}	19.30^{cde}	1.11^{bcdef}	2.31^{bcdef}	12.30^{b}	16.30^{b}	5.68^{ab}	7.95^{bc}
SEM		1.57	1.6	0.176	0.176	1.49	1.49	1.24	1.18

Main effects								
Concentration								
25%	5.95^{A}	11.1^{A}	0.56^{C}	1.35^{A}	9.22^{A}	11.9^{A}	2.27^{A}	3.82^{A}
50%	8.51^{B}	15.1^{B}	0.89^{B}	1.89^{C}	11.39^{A}	14.7^{B}	3.83^{A}	6.54^{B}
75%	6.65^{AB}	11.9^{A}	0.81^{AB}	1.61^{AB}	10.89^{A}	13.6^{AB}	3.79^{A}	4.27^{A}
100%	9.01^{B}	15.6^{B}	0.80^{AB}	1.8^{BC}	11.39^{A}	14.7^{B}	3.64^{A}	3.32^{A}
SEM	0.642	0.652	0.071	0.0718	0.608	0.608	0.508	0.482
Duration								
1	4.01^{AB}	9.93^{B}	0.385^{AB}	1.27^{B}	9.5^{B}	12.5^{B}	4.465^{B}	5.06^{BC}
2	6.76^{BC}	14.46^{C}	1.29^{C}	2.48^{C}	15.08^{C}	19.08^{C}	4.77^{B}	6.05^{BC}
3	10.66^{D}	18.56^{D}	1.44^{C}	2.63^{C}	16.5^{C}	20.5^{C}	4.18^{B}	6.309^{C}
4	9.51^{CD}	15.43^{CD}	0.679^{B}	1.57^{B}	10.42^{B}	13.42^{B}	2.39^{AB}	4.944^{BC}
6	11.41^{D}	17.33^{CD}	0.52^{AB}	1.42^{B}	9.75^{B}	12.75^{B}	3.67^{B}	3.816^{B}
8	2.84^{A}	4.82^{A}	0.27^{A}	0.57^{A}	3.08^{A}	4.08^{A}	0.69^{A}	0.738^{A}
SEM	0.786	0.798	0.087	0.0879	0.745	0.745	0.622	0.591
Values within the same column with similar superscripts are homogenous								

Table 40 Effect of biopriming with different concentrations of PGPR II at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

PGPR 2		Root Length (cm)		Number of Lateral Roots		Total Seedling Length (cm)	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
	1	-	-	-	-	-	-
	2	6.43^{bc}	11.33^{ef}	3.00^{ab}	5.00^{abc}	9.80^{abcd}	21.80^{bcde}

25%	3	4.87^{abc}	9.77^{bcdef}	4.67^{abc}	6.67^{abcd}	12.30^{bcd}	25.10^{bcdef}
	4	4.63^{abc}	9.53^{bcdef}	7.33^{bc}	9.33^{bcd}	16.43^{cde}	29.20^{def}
	6	3.30^{abc}	8.2^{bcdef}	4.33^{abc}	6.33^{abcd}	16.40^{cde}	29.20^{def}
	8	-	-	-	-	-	-
50%	1	1.67^{ab}	5.73^{bcd}	3.67^{abc}	5.33^{abcd}	5.23^{ab}	17.20^{bc}
	2	2.13^{ab}	5.17^{abc}	2.67^{ab}	4.00^{ab}	5.57^{ab}	16.50^{b}
	3	14.20^{e}	19.10^{h}	10.33^{c}	12.33^{d}	29.17^{fg}	42.00^{g}
	4	2.37^{ab}	4.93^{ab}	3.33^{abc}	5.33^{abcd}	16.53^{cde}	27.00^{bcdef}
	6	8.07^{cd}	12.97^{fg}	9.33^{bc}	11.33^{cd}	23.00^{efg}	35.80^{fg}
	8	-	-	-	-	-	-
75%	1	3.57^{abc}	6.63^{bcde}	3.00^{ab}	5.00^{abc}	7.87^{abc}	18.80^{bcd}
	2	3.90^{abc}	8.80^{bcdef}	4.33^{abc}	6.33^{abcd}	15.37^{bcde}	28.20^{cdef}
	3	4.80^{abc}	9.70^{bcdef}	3.67^{abc}	5.67^{abcd}	16.87^{cde}	29.70^{def}
	4	5.63^{bc}	10.53^{cdef}	7.67^{bc}	9.67^{bcd}	17.70^{cde}	30.50^{ef}
	6	-	-	-	-	-	-
	8	-	-	-	-	-	-
100%	1	4.53^{abc}	9.43^{bcdef}	6.67^{abc}	8.67^{bcd}	12.70^{bcde}	25.50^{bcdef}
	2	6.13^{bc}	11.03^{def}	3.67^{abc}	5.67^{abcd}	14.90^{bcde}	27.70^{bcdef}
	3	3.53^{abc}	8.43^{bcdef}	3.67^{abc}	5.00^{abc}	11.70^{bcde}	24.50^{bcde}
	4	-	-	-	-	-	-
	6	12.30^{de}	17.20^{gh}	2.67^{ab}	4.00^{ab}	18.97^{def}	31.80^{efg}
	8	7.60^{cd}	12.50^{fg}	6.00^{abc}	8.00^{bcd}	19.90^{g}	42.70^{g}
SEM		0.919	1.02	1.29	1.34	1.94	2.07
Main effects							
Concentration							
25%		3.21^{A}	6.47^{AB}	3.22^{A}	4.56^{A}	9.16^{A}	17.6^{A}
50%		4.74^{B}	7.98^{B}	4.89^{A}	6.39^{A}	13.25^{B}	23.1^{B}
75%		5.68^{B}	5.94^{A}	3.78^{A}	5.22^{A}	9.63^{A}	17.9^{A}
100%		2.98^{A}	9.77^{C}	3.11^{A}	4.44^{A}	14.69^{B}	25.4^{B}
SEM		0.375	0.415	0.525	0.549	0.794	0.846
Duration							

1	2.44^{A}	5.45^{B}	3.33^{AB}	4.75^{AB}	6.45^{A}	15.38^{B}
2	4.65^{BC}	9.08^{C}	3.42^{AB}	5.25^{B}	11.41^{B}	23.54^{CD}
3	6.85^{D}	11.75^{D}	5.58^{B}	7.42^{B}	17.51^{C}	30.31^{E}
4	3.16^{AB}	6.25^{B}	4.58^{B}	6.08^{B}	12.67^{B}	21.68^{C}
6	5.92^{CD}	9.59^{C}	4.08^{AB}	5.42^{B}	17.32^{C}	26.93^{DE}
8	1.90^{A}	3.12^{A}	1.50^{A}	2^{A}	4.74^{A}	7.94^{A}
SEM	0.46	0.508	0.643	0.672	0.972	1.04
Values within the same column with similar superscripts are homogenous						

4.6.3.2. Biomass production

Table 41 depict the variation in fresh weight biomass of the sandal seedlings bioprimed with PGPR II at different durations and concentrations. Stem fresh weight was the highest in the seedlings bioprimed at 50% for 3 days at 30 DAT (0.2733 g) and at 180 DAT (0.323 g) and the lowest was shown in seeds bioprimed at 50% for 2 days (0.063 g) at 30 DAT and that at 50 % for 1 day (0.07 g) at 180 DAT. For the first month of observation, the largest leaf fresh weight was shown in seedlings bioprimed at 75% for 3 days (1.14 g) and the lowest was shown in seeds bioprimed at 50% for 1 day (0.167 g). During 6^{th} month, seeds bioprimed at 75% for 3 days (1.33 g) recorded the highest leaf fresh weight and those at 50% for 1 day (0.337 g) recorded the lowest leaf fresh weight. While, the root fresh weight at 30 DAT was the highest in seedlings bioprimed at 75% for 2 days (0.463 g) and the lowest in those at 100% for 1day (0.053 g). At 180 DAT seedlings bioprimed at 75% for 2 days (0.553 g) and 50 % for 1 day (0.093 g) respectively recorded the highest and lowest root fresh weight (For the first month of observation the largest total fresh weight was observed in seedlings bioprimed at 75% for 3 days (1.72 g) and the lowest was in those at 50 % for 4days (0.427g). During 6^{th} month also, the seedlings bioprimed at 75% for 3 days (2.11 g) recorded the highest total fresh weight and the seeds bioprimed at 100 % for 6 days recorded the lowest fresh weight (0.713 g).

Statistical analysis revealed significant difference in fresh weight of stem ($F=1.950$, $p < 0.05$), leaf ($F=20.482$, $p < 0.01$) and root ($F=6.380$, $p < 0.01$) and total fresh weight ($F=16.837$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT and the interaction was also significant at 180 days in fresh weight of stem ($F=7.412$, $p < 0.01$), leaf ($F=28.521$, $p < 0.01$) and root ($F=9.578$, $p < 0.01$) and total fresh weight ($F=29.689$, $p< 0.01$).

The effect of biopriming with PGPR II on dry biomass production of the seedlings is given in Table 42. The highest stem dry weight was shown in seedlings bioprimed at 25 % for 2 days (0.191 g) and the lowest was in in seedlings bioprimed at 50% for 1day (0.021 g) at 30 DAT. At 180 DAT, seedlings bioprimed at 25% for 2 days (0.216 g) recorded the highest stem dry weight and the seedlings bioprimed at 50% for 1 day (0.036 g) recorded the lowest. The seedlings with largest leaf dry weight was observed in biopriming at 50 % for 6 days (0.216 g) and lowest was in those bioprimed at 50% for 1 day (0.09 g). At 180 DAT, seedlings bioprimed at 50% for 6 days, 75% for 2 days and 100% for 2 days (0.3g) recorded the highest dry weight (leaf) and the seeds bioprimed at 50 % for 1 day (0.11 g) recorded the lowest value. The largest root dry weight was recorded in seedlings bioprimed at 100% for 2 days and 50% for 3 days (0.17 g) and the lowest was shown in seeds bioprimed at 100% for 1 day (0.026 g) at 30 DAT. At 180 DAT, seeds bioprimed at 100% for 2 days (0.196 g) recorded the highest root dry weight and the seeds bioprimed at 50% for 1 day (0.063 g) recorded the lowest value. When the total biomass production was compared the largest dry weight was shown in seedlings bioprimed at 75% for 1 day (0.844 g) and the lowest dry weight was shown in seeds bioprimed at 50% for 1 day (0.118 g) at 30 DAT. At 180 DAT, also seeds bioprimed at 75% for 3 days (1.41 g) recorded the highest dry weight and the seedlings bioprimed at 50% for 1 day (0.21 g) recorded the lowest dry weight.

Statistical analysis revealed significant difference in dry weight of stem ($F=1.965$, $p < 0.05$), leaf ($F=20.539$, $p < 0.01$) and root ($F=6.688$, $p < 0.01$) and total dry weight ($F=16.906$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT and the interaction was also significant at 180 days in dry weight of

stem($F=2.314$ $p < 0.05$), leaf ($F=10.387$, $p < 0.01$) and root ($F=29.689$, $p < 0.01$) and total dry weight ($F=10.177$, $p < 0.01$).

Table 41 Effect of biopriming with different concentrations of PGPR II at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

PGPR 2		Fresh weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-	-	-
	2	0.273^{abc}	0.460^{bcd}	0.286^{b}	0.396^{e}	0.160^{abcd}	0.250^{bcde}	0.720^{bcde}	1.110^{cdef}
	3	0.180^{ab}	0.370^{bc}	0.180^{ab}	0.290^{bcde}	0.110^{abcd}	0.200^{abcde}	0.470^{abc}	0.860^{bcd}
	4	0.260^{abc}	0.450^{bcd}	0.126^{ab}	0.240^{abcde}	0.060^{ab}	0.150^{abc}	0.447^{abc}	0.837^{bcd}
	6	0.280^{abc}	0.470^{bcd}	0.120^{ab}	0.230^{abcde}	0.253^{bcde}	0.343^{cdef}	0.660^{bcd}	1.050^{bcde}
	8	-	-	-	-	-	-	-	-
50%	1	0.167^{ab}	0.337^{ab}	0.066^{ab}	0.070^{ab}	0.083^{abc}	0.093^{ab}	0.327^{ab}	0.507^{ab}
	2	0.313^{abc}	0.500^{bcd}	0.063^{ab}	0.170^{abcde}	0.180^{abcd}	0.270^{bcde}	0.557^{abc}	0.940^{bcd}
	3	1.100^{e}	1.290^{f}	0.273^{ab}	0.323^{de}	0.340^{de}	0.430^{ef}	1.713^{f}	2.103^{g}
	4	0.203^{ab}	0.393^{bc}	0.0733^{ab}	0.120^{abc}	0.150^{abcd}	0.210^{abcde}	0.427^{ab}	0.720^{bc}
	6	0.473^{bcd}	0.600^{bcde}	0.12^{ab}	0.160^{abcde}	0.260^{bcde}	0.350^{cdef}	0.853	1.170^{cdef}
	8	-	-	-	-	-	-	-	-
75%	1	0.807^{de}	0.990^{ef}	0.213^{ab}	0.320^{cde}	0.246^{bcde}	0.340^{bcdef}	1.267^{ef}	1.650^{fg}
	2	0.567^{cd}	0.750^{de}	0.160^{ab}	0.270^{bcde}	0.463^{e}	0.553^{f}	1.190^{def}	1.580^{efg}
	3	1.140^{e}	1.330^{f}	0.263^{ab}	0.373^{de}	0.313^{cde}	0.403^{def}	1.720^{f}	2.110^{g}
	4	0.380^{bc}	0.570^{bcd}	0.110^{ab}	0.220^{abcde}	0.086^{abc}	0.176^{abcd}	0.570^{abc}	0.967^{bcd}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
100%	1	0.337^{abc}	0.530^{bcd}	0.130^{ab}	0.240^{bcde}	0.053^{ab}	0.143^{abc}	0.520^{abc}	0.910^{bcd}
	2	0.487^{bcd}	0.700^{bcde}	0.193^{ab}	0.303^{bcde}	0.340^{de}	0.430^{ef}	1.020^{cde}	1.410^{def}
	3	0.273^{abc}	0.460^{bcd}	0.068^{ab}	0.093^{abc}	0.156^{abcd}	0.240^{abcde}	0.610^{bcd}	0.803^{bc}
	4	-	-	-	-	-	-	-	-
	6	0.247^{abc}	0.430^{bcd}	0.143^{ab}	0.120^{abc}	0.073^{abc}	0.163^{abcd}	0.463^{abc}	0.713^{bc}
	8	0.517^{bcd}	0.710^{cde}	0.0433^{ab}	0.153^{abcd}	0.183^{abcd}	0.273^{bcde}	0.740^{bcde}	1.130^{cdef}
SEM		0.0652	0.0658	0.0521	0.1533	0.0451	0.0457	0.108	0.109
Main effects									

Concentration								
25%	0.167^{A}	0.29^{A}	0.119^{A}	0.192^{A}	0.097^{A}	0.157^{A}	0.38^{A}	0.643^{A}
50%	0.376^{B}	0.53^{BC}	0.101^{A}	0.152^{A}	0.168^{B}	0.225^{AB}	0.646^{BC}	0.908^{BC}
75%	0.483^{C}	0.61^{C}	0.124^{A}	0.198^{A}	0.185^{B}	0.245^{B}	0.793^{C}	1.05^{C}
100%	0.31^{B}	0.468^{B}	0.115^{A}	0.152^{A}	0.134^{AB}	0.209^{AB}	0.559^{B}	0.828^{B}
SEM	0.0266	0.0269	0.0213	0.018	0.0184	0.0187	0.0444	0.044
Duration								
1	0.328^{BC}	0.46^{BC}	0.105^{AB}	0.16^{B}	0.095^{AB}	0.143^{AB}	0.52^{B}	0.768^{B}
2	0.41^{C}	0.6^{C}	0.175^{BC}	0.285^{C}	0.285^{D}	0.375^{C}	0.87^{C}	1.262^{C}
3	0.675^{D}	0.86^{D}	0.224^{C}	0.285^{C}	0.23^{CD}	0.32^{C}	1.12^{D}	1.47^{C}
4	0.211^{AB}	0.35^{B}	0.0775^{AB}	0.144^{B}	0.074^{AB}	0.133^{AB}	0.36^{AB}	0.631^{B}
6	0.252^{AB}	0.39^{B}	0.095^{AB}	0.127^{AB}	0.146^{BC}	0.214^{B}	0.49^{B}	0.734^{B}
8	0.129^{A}	0.177^{A}	0.01^{A}	0.0383^{A}	0.045^{A}	0.068^{BCDE}	0.186^{A}	0.283^{A}
SEM	0.0326	0.0329	0.026	0.022	0.0226	0.0229	0.0544	0.0539
Values within the same column with similar superscripts are homogenous								

Table 42 Effect of biopriming with different concentrations of PGPR II at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

PGPR 2		Dry weight (g)							
		Leaf		Shoot		Root		Total	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-	-	-
	2	0.182^{abc}	0.196^{ab}	0.191^{b}	0.216^{ab}	0.080^{abcd}	0.120^{abcde}	0.480^{bcde}	0.490^{abc}
	3	0.120^{ab}	0.160^{ab}	0.120^{ab}	0.126^{ab}	0.055^{abcd}	0.110^{abcde}	0.313^{abc}	0.400^{ab}

	4	0.173^{abc}	0.230^{ab}	0.084^{ab}	0.233^{ab}	0.030^{ab}	0.076^{abc}	0.298^{abc}	0.540^{abc}
	6	0.181^{abc}	0.190^{ab}	0.080^{ab}	0.090^{ab}	0.126^{bcde}	0.200^{cde}	0.440^{bcd}	0.490^{abc}
	8	-	-	-	-	-	-	-	-
50%	1	0.090^{ab}	0.110^{ab}	0.021^{ab}	0.036^{ab}	0.042^{abc}	0.063^{ab}	0.118^{ab}	0.210^{ab}
	2	0.209^{abc}	0.260^{ab}	0.042^{ab}	0.100^{ab}	0.090^{abcd}	0.160^{bcde}	0.371^{abc}	0.520^{abc}
	3	0.733^{e}	0.980^{d}	0.150^{ab}	0.163^{ab}	0.170^{de}	0.213^{de}	1.140^{f}	1.260^{cd}
	4	0.136^{ab}	0.190^{ab}	0.048^{ab}	0.056^{ab}	0.075^{abcd}	0.096^{abcd}	0.284^{ab}	0.350^{ab}
	6	0.216^{bcd}	0.300^{abc}	0.080^{ab}	0.096^{ab}	0.130^{bcde}	0.166^{bcde}	0.570^{bcde}	0.580^{bcd}
	8	-	-	-	-	-	-	-	-
75%	1	0.530^{de}	0.550^{cd}	0.142^{ab}	0.350^{b}	0.1230^{bcde}	0.186^{bcde}	0.844^{ef}	1.150^{d}
	2	0.170^{bc}	0.270^{ab}	0.106^{ab}	0.113^{ab}	0.221^{e}	0.230^{e}	0.593^{def}	0.620^{bcd}
	3	0.760^{e}	0.220^{ab}	0.175^{ab}	0.0933^{ab}	0.156^{cde}	0.090^{abcd}	1.140^{f}	1.410^{d}
	4	0.250^{bc}	0.300^{abc}	0.073^{ab}	0.126^{ab}	0.043^{abc}	0.110^{abcde}	0.380^{abc}	0.570^{abc}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
100%	1	0.124^{abc}	0.180^{ab}	0.086^{ab}	0.160^{ab}	0.026^{ab}	0.096^{abcd}	0.347^{abc}	0.440^{ab}
	2	0.220^{bcd}	0.300^{abc}	0.128^{ab}	0.156^{ab}	0.170^{de}	0.196^{cde}	0.580^{cde}	0.650^{bcd}
	3	0.182^{abc}	0.230^{ab}	0.120^{ab}	0.160^{ab}	0.078^{abcd}	0.126^{bcde}	0.407^{bcd}	0.420^{ab}
	4	-	-	-	-	-	-	-	-
	6	0.164^{abc}	0.250^{ab}	0.095^{ab}	0.200^{ab}	0.036^{abc}	0.070^{ab}	0.309^{abc}	0.520^{abc}
	8	0.344^{bcd}	0.400^{bcd}	0.028^{ab}	0.083^{ab}	0.091^{abcd}	0.120^{abcde}	0.490^{bcde}	0.600^{bcd}
SEM		0.0434	0.0608	0.0347	0.0632	0.0226	0.0231	0.0725	0.106
Main effects									
Concentration									
25%		0.111^{A}	0.13^{A}	0.079^{A}	0.111^{A}	0.048^{A}	0.084^{A}	0.255^{A}	0.322^{A}
50%		0.251^{B}	0.26^{B}	0.067^{A}	0.075^{A}	0.084^{B}	0.117^{A}	0.431^{BC}	0.452^{A}
75%		0.322^{C}	0.24^{B}	0.089^{A}	0.11^{A}	0.082^{B}	0.103^{A}	0.529^{C}	0.458^{A}
100%		0.207^{B}	0.23^{B}	0.076^{A}	0.11^{A}	0.067^{AB}	0.102^{A}	0.373^{B}	0.439^{A}
SEM		0.0177	0.0248	0.0142	0.0258	0.00921	0.00944	0.0296	0.0433
Duration									
1		0.11^{AB}	0.2^{ABC}	0.07^{AB}	0.136^{A}	0.047^{AB}	0.086^{BC}	0.352^{B}	0.45^{B}

2	0.233^{C}	0.25^{BC}	0.117^{BC}	0.146^{A}	0.142^{D}	0.176^{D}	0.561^{C}	0.57^{B}
3	0.25^{B}	0.33^{C}	0.149^{C}	0.150^{A}	0.115^{CD}	0.135^{CD}	0.453^{BC}	0.57^{B}
4	0.14^{AB}	0.18^{AB}	0.050^{AB}	0.104^{A}	0.037^{AB}	0.072^{AB}	0.242^{AB}	0.365^{AB}
6	0.167^{AB}	0.19^{AB}	0.063^{AB}	0.096^{A}	0.073^{BC}	0.109^{BC}	0.329^{B}	0.397^{B}
8	0.086^{A}	0.1^{A}	0.007^{A}	0.021^{A}	0.0229^{A}	0.03^{A}	0.124^{A}	0.151^{A}
SEM	0.0217	0.0304	0.0174	0.0316	0.0113	0.0116	0.0362	0.053
Values within the same column with similar superscripts are homogenous								

4.6.3.3. Plant growth analysis indices and vigour index

The effect of biopriming of sandal seedlings with PGPR II at different concentrations and durations on the leaf area ratio, leaf weight ratio, and root: shoot ratio and vigour index is given in the Table 43. LAR was the highest in seedlings bioprimed at 50% for 1 day (23.76 $cm^2 g^{-1}$) and the lowest was in seeds bioprimed at 100% for 6 days (2.89 $cm^2 g^{-1}$) during first month of observation. During 6^{th} month, seeds bioprimed at 50% for 1 day (65.68 $cm^2 g^{-1}$) recorded the highest leaf area ratio and the seeds bioprimed at 100 % for 8 days (4.89 $cm^2 g^{-1}$) recorded the lowest value. At 30 DAT, the largest LWR was shown in seedlings bioprimed at 50% for 3 days (0.647) and the lowest was shown at 25% for 6 days (0.222). At 180 DAT, seeds bioprimed at 50% for 3 days (0.71) and 25% for 6 days (0.39) recorded the highest and the lowest LWR. For the first month of observation the largest root: shoot was shown in seedlings bioprimed at 100 % for 1 day (0.262) and the lowest was shown in seeds bioprimed at 25% for 4 days (0.079). During 6^{th} month, seedlings bioprimed at 100% for 6 days (0.9216) recorded the highest root: shoot ratio and the seeds bioprimed at 75% for 4 days (0.054) recorded the lowest value. The largest VI was shown in seedlings bioprimed at 50% for 3 days (2241.7) and the lowest was shown in seeds bioprimed at 75% for 1 day (31.5) at 30 DAT. Similarly, at 180 DAT, seedlings bioprimed at 50% for 3 days (3223) recorded the highest VI and the seeds bioprimed at 75% for 1 day (75.3) recorded the lowest VI. Analysis of variance revealed significant difference in leaf area ratio ($F=3.611$, $p < 0.01$), leaf weight ratio ($F=16.406$, $p < 0.01$) root: shoot ratio ($F=4.864$, $p < 0.01$) and vigour index ($F=35.695$, $p < 0.01$) due to interaction between concentration and duration at 30 DAT. The interaction was also significant at 180 days in leaf area ratio ($F=4.273$, $p < 0.01$), leaf weight ratio ($F=24.402$, $p < 0.01$), root: shoot ratio ($F=6.280$, $p < 0.01$) and vigour index ($F=68.481$, $p < 0.01$).

Table 43 Effect of biopriming with different concentrations of PGPR II at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

PGPR 2		Leaf Area Ratio (cm2g-1)		Leaf Weight Ratio		Root : Shoot ratio		Vigor index	
Concentration	Duration (days)	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
25%	1	-	-	-	-	-	-	0.0^{a}	-
	2	11.45^{ab}	16.20^{a}	0.315^{b}	0.325^{b}	0.121^{ab}	0.336^{abcd}	183.3^{ab}	$408^{abcdefg}$
	3	11.19^{ab}	12.02^{a}	0.393^{b}	0.417^{bc}	0.142^{ab}	0.414^{bcd}	361.5^{abcd}	737^{efgh}
	4	5.58^{ab}	12.34^{a}	0.598^{b}	0.480^{bc}	0.079^{ab}	0.197^{ab}	98.6^{ab}	175.4^{abc}
	6	6.07^{ab}	9.44^{a}	0.222^{b}	0.390^{bc}	0.244^{b}	0.675^{d}	467.3^{bcd}	834^{gh}
	8	-	-	-	-	-	-	-	-
50%	1	23.76^{b}	65.68^{b}	0.457^{b}	0.480^{bc}	0.127^{ab}	0.468^{bcd}	107.3^{ab}	353^{abcdef}
	2	9.20^{ab}	14.28^{a}	0.320^{b}	0.490^{bc}	0.231^{b}	0.460^{bcd}	100.2^{ab}	297^{abcde}
	3	5.55^{ab}	7.56^{a}	0.647^{b}	0.710^{c}	0.121^{ab}	0.310^{cbcd}	2241.7^{e}	3223^{i}
	4	20.77^{b}	28.44^{a}	0.338^{ab}	0.540^{bc}	0.248^{b}	0.390^{abcd}	476.8^{bcd}	777^{fgh}
	6	11.33^{ab}	11.79^{a}	0.453^{b}	0.550^{bc}	0.199^{ab}	0.404^{bcd}	261.5^{abc}	$406^{abcdefg}$
	8	-	-	-	-	-	-	-	-
75%	1	4.32^{ab}	6.62^{a}	0.440^{b}	0.570^{bc}	0.127^{ab}	0.224^{abc}	31.5^{a}	75.3^{ab}
	2	8.59^{ab}	10.54^{a}	0.427^{b}	0.448^{bc}	0.259^{b}	0.597^{cd}	718.5^{d}	1316^{i}
	3	3.39^{ab}	17.9^{a}	0.367^{b}	0.550^{bc}	0.120^{ab}	0.300^{abcd}	101.2^{ab}	178^{abc}
	4	9.51^{ab}	10.10^{a}	0.471^{b}	0.566^{bc}	0.090^{ab}	0.054^{abc}	365.4^{abcd}	630^{defg}
	6	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-
100%	1	8.13^{ab}	16.88^{a}	0.438^{b}	0.613^{bc}	0.262^{ab}	0.272^{abcd}	101.6^{ab}	204^{abcd}
	2	6.10^{ab}	6.62^{a}	0.484^{b}	0.495^{bc}	0.244^{b}	0.452^{bcd}	636.3^{cd}	1182^{hi}
	3	7.78^{ab}	18.19^{a}	0.445^{b}	0.565^{bc}	0.200^{ab}	0.438^{bcd}	179.1^{ab}	375^{abcdef}
	4	-	-	-	-	-	-	-	-
	6	2.89^{a}	6.96^{a}	0.477^{b}	0.490^{bc}	0.121^{ab}	0.922^{abc}	341.1^{abcd}	486^{bcdefg}
	8	3.69^{a}	4.89^{a}	0.500^{b}	0.642^{c}	0.169^{ab}	0.256^{abc}	330.9^{abcd}	552^{cdefg}
SEM		3.78	6.44	0.0672	0.0475	0.1691	0.073	78.6	82.3

Main effects								
Concentration								
25%	6.05^{AB}	8.34^{A}	0.30^{A}	0.371^{B}	0.0981^{A}	0.271^{A}	185^{A}	843^{B}
50%	11.77^{B}	21.29^{B}	0.436^{B}	0.448^{C}	0.154^{A}	0.34^{A}	531^{B}	667^{A}
75%	5.3^{A}	7.53^{A}	0.309^{B}	0.356^{B}	0.099^{A}	0.229^{A}	203^{A}	467^{A}
100%	10.27^{AB}	16.92^{AB}	0.454^{B}	0.489^{BC}	0.133^{A}	0.276^{A}	265^{A}	359^{A}
SEM	1.54	2.63	0.0274	0.0194	0.0153	0.0298	32.1	33.6
Duration								
1	12.55^{B}	19.79^{B}	0.259^{B}	0.367^{B}	0.079^{AB}	0.244^{BC}	60.1^{A}	158^{A}
2	8.84^{AB}	11.4^{AB}	0.427^{BC}	0.441^{B}	0.214^{C}	0.462^{D}	409.6^{D}	801^{C}
3	7.48^{AB}	13.9^{AB}	0.538^{C}	0.586^{C}	0.146^{BC}	0.365^{CD}	720.9	1128^{D}
4	9.47^{AB}	12.7^{AB}	0.402^{BC}	0.499^{B}	0.104^{AB}	0.21^{AB}	235.2^{BC}	395^{B}
6	10.07^{B}	17.1^{AB}	0.388^{B}	0.391^{B}	0.141^{BC}	0.323^{BCD}	267.5^{CD}	432^{B}
8	1.67^{A}	1.82^{A}	0.135^{A}	0.161^{A}	0.042^{A}	0.0649^{A}	82.7^{AB}	138^{A}
SEM	1.89	3.22	0.0336	0.0237	0.0187	0.0365	39.3	41.1
Values within the same column with similar superscripts are homogenous								

4.6.4. Hydropriming

4.6.4.1. Seedling Growth

The impact of hydropriming at different durations on the shoot parameters of sandal seedlings are presented in Table44. At 30 DAT, the highest seedling height was shown in seedlings hydroprimed for 8 days (14.23 cm) and lowest was shown in seeds hydroprimed for 3 days (5.97 cm). During 180 DAT also the seedlings hydroprimed for 8 days (22.11 cm) recorded the highest seedling height and the seeds hydroprimed for 3 days (13.9 cm) recorded the lowest seedling height. However, the largest collar diameter was shown in seedlings hydroprimed for 8 days (2.243 mm) and lowest was in those hydroprimed for 3 days (0.473 mm) at 30 DAT. Similar trend was observed at 180 DAT also and the seeds hydroprimed for 8 days (3.43 mm) recorded the highest collar diameter and the seeds hydroprimed for 3 days (1.66 mm) recorded the lowest collar diameter. While, the highest leaf number during 30 DAT was shown in seedlings hydroprimed for 3 days (16.3) and the lowest was shown in seeds hydroprimed for 4 days (15). At 180 DAT, seeds hydroprimed for 3 days (20.3) recorded the highest leaf number and the seeds hydroprimed for 4 days (19) recorded the lowest leaf number. For first month, the largest leaf area was shown in seedlings hydroprimed for 2 days (5.15 cm^2) and the lowest was shown in seeds hydroprimed for 8 days (2.32 cm^2).During 6^{th} month, seedlings hydroprimed for 1day (7.76 cm^2) showed the highest leaf area and those for 6 days (3.08 cm^2) recorded the least values. Analysis of variance revealed significant difference in seedling height ($F=3.788$, $p < 0.05$), collar diameter ($F=21.875$, $p < 0.05$) and leaf area ($F=7.894$, $p<0.01$) due to hydropriming duration but leaf number ($F=0.162$, $p =0.972$) and leaf area ($F=0.713$, $p=0.625$) of the seedlings were not significant at 30 DAT. At 180 DAT also seedling height ($F=3.788$, $p < 0.05$), collar diameter ($F=21.875$, $p<0.05$), and leaf area ($F=4.590$, $p < 0.05$) of the seedlings varied with hydropriming duration but the leaf number ($F=0.162$, $p =0.972$) was not significantly different.

Effect of hydropriming on the root parameters of sandal seedlings are presented in Table 45. For first month, the highest root length was shown in seedlings hydroprimed for 6 days (10.7 cm) and lowest was shown in seeds hydroprimed for 8days (3.87 cm). Seedlings hydroprimed for 6 days (15.60 cm) recorded the highest root length and the seeds hydroprimed for 8 days (7.87) recorded the lowest root length at 6^{th} month. The largest number of roots at 30 DAT was present in seedlings hydroprimed for 2 days (9.33) and the lowest was in hydropriming for 4 days (3.00). At 180 DAT, seeds hydroprimed at for 2days (11.33) recorded the highest number of roots and the seeds hydroprimed for 1day (4) recorded the lowest number of roots.

For first month the largest total seedling length was shown in seedlings hydroprimed for 1 day and 6 days (23.5 cm) and the lowest was in those hydroprimed for 3 days (10.8 cm). During 6^{th} month, seeds hydroprimed for 1 day and 6 days (36.3 cm) recorded the highest total seedling length and the seeds hydroprimed for 3 days (23.6 cm) recorded the lowest total seedling length.

Analysis of variance revealed significant difference in total seedling length ($F=3.687$, $p<0.05$) due to hydropriming duration but variation in root length ($F=2.278$, $p=0.113$) and root number ($F=2.754$, $p=0.070$) were not significant at 30 DAT. At 180 DAT also differences in root length ($F=2.381$, $p=0.101$) and root number ($F=3.074$, $p =0.051$) were not significant but total length ($F=3.870$, $p < 0.05$) of the seedlings differed significantly with hydropriming duration.

Table 44 Effect of hydropriming at various durations on the shoot growth attributes of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Hydropriming (Days)	Shoot height (cm)		Collar Girth (mm)		Leaf number		Leaf Area (cm^2)	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	13.37^{ab}	21.30^{ab}	0.567^{a}	1.76^{a}	15.70^{a}	19.70^{a}	3.28^{a}	7.76^{b}
2	7.80^{ab}	15.70^{ab}	0.770^{a}	1.96^{a}	16.00^{a}	20.00^{a}	5.15^{a}	5.85^{ab}
3	5.97^{a}	13.90^{a}	0.473^{a}	1.66^{a}	16.30^{a}	20.30^{a}	4.06^{a}	6.69^{ab}
4	10.93^{ab}	18.80^{ab}	0.747^{a}	1.94^{a}	15.00^{a}	19.00^{a}	3.58^{a}	3.90^{ab}
6	12.83^{ab}	20.71^{ab}	1.783^{a}	2.97^{b}	15.70^{a}	19.70^{a}	2.33^{a}	3.08^{a}
8	14.23^{b}	22.11^{b}	2.243^{a}	3.43^{b}	16.00^{a}	2.00^{a}	2.32^{a}	6.82^{ab}
SEM	1.7	1.712	0.157	0.157	1.13	1.13	1.28	0.851
Values within the same column with similar superscripts are homogenous.								

Table 45 Effect of hydropriming at various durations on the root growth attributes of sandal seedlings subjected at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Hydropriming (Days)	Number of Lateral Roots		Root Length (cm)		Total Seedling Length (cm)	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	3.33^{a}	4.00^{a}	10.13^{a}	15.03^{a}	23.50^{b}	36.30^{b}
2	9.33^{a}	11.33^{b}	7.53^{a}	12.43^{a}	15.30^{ab}	28.10^{ab}
3	4.67^{a}	6.67^{ab}	4.87^{a}	9.77^{a}	10.80^{a}	23.60^{a}
4	3.00^{a}	5.00^{ab}	5.70^{a}	10.60^{a}	16.60^{ab}	29.40^{ab}
6	3.33^{a}	5.33^{ab}	10.70^{a}	15.60^{a}	23.50^{b}	36.30^{b}
8	5.67^{a}	7.67^{ab}	3.87^{a}	7.87^{a}	18.12^{ab}	3^{-b}
SEM	1.45	1.5	1.87	1.97	2.56	2.51
Values within the same column with similar superscripts are homogenous.						

4.6.4.2. Biomass production

Variation in fresh weight of sandal seedlings with hydropriming duration is presented in Table 46. For the first month, the largest stem fresh weight was shown in seedlings hydroprimed for 1 days (0.170 g) and the lowest was shown in seeds hydroprimed for 4 days (0.107 g). During 6th month, seeds hydroprimed at 3 days (0.2667 g) recorded the highest weight and the seeds hydroprimed for 8 days (0.1367 g) recorded the lowest fresh weight (stem). The highest leaf fresh weight was recorded in seedlings hydroprimed for 6 days (1.390 g) and the lowest was shown in seedlings hydroprimed for 2 days (0.363 g) at 30 DAT. During 180 days, seeds hydroprimed at 6 days (1.580 g) recorded the highest leaf fresh weight and the seeds hydroprimed for 2 days (0.533 g) recorded the lowest fresh weight (leaf). At 30 DAT, root fresh weight was the highest in the seedlings hydroprimed for 1day (0.543 g) and the lowest was shown in seeds hydroprimed for 4 days (0.137 g). At 180 DAT, seeds hydroprimed for 1day (0.633 g) recorded the highest fresh weight (roots) and the seeds hydroprimed for 4 days (0.207 g) recorded the lowest value. Regarding the total fresh weight, the highest value was shown in seedlings hydroprimed for 6 days (1.817 g) and the lowest was in hydropriming for 2days (0.743 g) at 30 DAT. At 180 DAT, seeds hydroprimed for 6 days (2.210 g) recorded the highest total fresh weight and the seeds hydroprimed for 2 days (1.130 g) recorded the lowest total fresh weight Statistical analysis revealed significant differences in fresh weight of stem ($F=0.323, p=0.889$), root ($F=1.634$, $p=0.225$) and leaf ($F=10.270$, $p < 0.01$) but total fresh weight ($F=2.759, p=0.70$) was not significant but l are significant due to hydropriming duration at 30 DAT and the variation was also significant at 180 days in fresh weight of leaf ($F=10.270$, $p < 0.01$) and root ($F=1.718$, $p < 0.05$) and total fresh weight($F=6.632$, $p < 0.01$) but not significant in stem fresh weight ($F=2.751$, $p=0.070$).

Variation in dry weight biomass of hydroprimed seedlings are presented in Table 47. For first month the largest stem dry weight was shown in seedlings hydroprimed for 3 days (0.1778 g) and the lowest was shown in seeds hydroprimed for 8 days (0.0311 g). During 6th month, seeds hydroprimed for 3 days (0.2433 g) recorded the highest stem dry weight and the seeds hydroprimed for 8 days (0.0664 g) recorded the lowest stem dry weight. The largest dry weight (leaf) was shown in seedlings hydroprimed for 6days (0.873 g) and the lowest was shown in seedlings hydroprimed for 1day (0.203 g) at 30 DAT. At 180 DAT, seeds hydroprimed at 6 days (0.927 g) recorded the highest dry weight (leaf) and the seeds hydroprimed for 2 days (0.242 g) recorded the lowest dry weight (leaf). For first month the largest dry weight (roots) was shown in seedlings hydroprimed for 1day (0.27 g) and lowest was shown in seeds hydroprimed for 4days (0.0683 g).During 6th month, seeds hydroprimed for 1day (0.280 g) recorded the highest dry weight (root) and the seeds hydroprimed for 4 days (0.090 g) recorded the lowest dry weight (roots). Comparing total dry weight at 30 DAT, the largest total dry weight was shown in seedlings hydroprimed 6 days (1.170 g) and the lowest was shown in seeds hydroprimed for 1 day (0.402 g). At 180 DAT, seeds hydroprimed for 6 days (1.211 g) recorded the highest total dry weight and the seeds hydroprimed for 1 day (0.427 g) recorded the lowest total dry weight.

Statistical analysis revealed significant difference in dry weight of stem($F=4.642$, $p <0.05$), leaf ($F=10.228$, $p < 0.01$) but root ($F=1.709$, $p =0.207$) and total dry weight ($F=2.748, p=0.07$) were not significant due to hydropriming duration at 30 DAT and the effect of duration was also significant at 180 days in dry weight of stem ($F=4.104$, $p <0.05$), leaf ($F=25.526$, $p < 0.01$) and total dry weight ($F=14.153$, $p < 0.01$) but dry weight of roots ($F=1.101$, $p=0.409$) was not significant.

Table 46 Effect of hydropriming at various durations on the fresh weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Hydropriming (Days)	Fresh Weight (g)							
	Leaf		Shoot		Root		Total	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	0.477^{a}	0.667^{a}	0.170^{a}	0.183^{a}	0.543^{a}	0.633^{a}	1.203^{a}	1.470^{a}
2	0.363^{a}	0.533^{a}	0.150^{a}	0.167^{a}	0.323^{a}	0.413^{a}	0.743^{a}	1.130^{a}
3	0.583^{a}	0.773^{a}	0.110^{a}	0.267^{a}	0.330^{a}	0.420^{a}	1.180^{a}	1.190^{a}
4	1.273^{bc}	1.463^{bc}	0.107^{a}	0.143^{a}	0.137^{a}	0.207^{a}	1.553^{a}	1.780^{ab}
6	1.390^{c}	1.580^{c}	0.127^{a}	0.147^{a}	0.280^{a}	0.370^{a}	1.817^{a}	2.210^{b}
8	0.647^{ab}	0.837^{ab}	0.129^{a}	0.137^{a}	0.270^{a}	0.360^{a}	1.053^{a}	1.330^{a}
SEM	0.135	0.135	0.121	0.121	0.103	0.105	0.228	0.253
Values within the same column with similar superscripts are homogenous.								

Table 47 Effect of hydropriming at various durations on the dry weight of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Hydropriming (Days)	Dry Weight (g)							
	Leaf		Shoot		Root		Total	
	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT	30 DAT	180DAT
1	0.203^{a}	0.318^{a}	0.122^{a}	0.142^{b}	0.272^{a}	0.280^{a}	0.402^{a}	0.427^{a}
2	0.207^{a}	0.242^{a}	0.038^{a}	0.097^{ab}	0.162^{a}	0.177^{a}	0.496^{a}	0.580^{ab}
3	0.260^{a}	0.389^{a}	0.178^{a}	0.243^{ab}	0.165^{a}	0.230^{a}	0.487^{a}	0.533^{a}
4	0.800^{b}	0.849^{bc}	0.096^{a}	0.099^{a}	0.068^{a}	0.090^{a}	0.950^{bc}	1.036^{a}
6	0.873^{b}	0.927^{c}	0.098^{a}	0.140^{b}	0.140^{a}	0.157^{a}	1.170^{c}	1.211^{a}
8	0.263^{a}	0.431^{ab}	0.031^{a}	0.067^{ab}	0.135^{a}	0.180^{a}	0.510^{a}	0.702^{a}
SEM	0.0596	0.0901	0.0803	0.0812	0.0517	0.04	0.0785	0.152
Values within the same column with similar superscripts are homogenous.								

4.6.4.3. Plant growth analysis indices and vigour index

Variation in Plant growth analysis indices and vigour index of the seedlings subjected to hydropriming are given in Table 48. Analysis of variance revealed significant difference in leaf area ratio ($F=3.130$, $p < 0.05$), leaf weight ratio ($F=8.889$, $p < 0.01$) and vigour index ($F=18.517$, $p < 0.01$) due to hydropriming duration but the variation in root: shoot ratio ($F=2.961$, $p =0.057$) was not significant at 30 DAT. The effect of hydropriming duration was also significant at 180 days in leaf area ratio ($F=5.702$, $p < 0.01$), leaf weight ratio ($F=5.194$, $p < 0.01$) root: shoot ratio ($F=3.988$, $p < 0.05$) and vigour index ($F=46.615$, $p < 0.01$).

For first month the largest leaf area ratio was shown in seedlings hydroprimed for 2 days (10.32 $cm^2 g^{-1}$) and the lowest was shown in seeds hydroprimed for 8 days (3.69 $cm^2 g^{-1}$). During 6^{th} month, seedlings hydroprimed for 1 day (18.26 $cm^2 g^{-1}$) recorded the highest LAR and the seedlings hydroprimed for 6 days (2.67 $cm^2 g^{-1}$) recorded the least value Meanwhile, for first month the largest LWR was shown in seedlings hydroprimed for 4 days (0.833) and the lowest was shown in seeds hydroprimed for 1day (0.435). During 6^{th} month, seeds hydroprimed for 4days (0.856) recorded the LWR and the seeds hydroprimed for 1day (0.476) recorded the lowest leaf weight ratio. Variation in root: shoot ratio of hydroprimed seedlings indicated that largest root: shoot ratio at 30 DAT was shown in seedlings hydroprimed for2 days (0.3030) and the lowest was shown in seeds hydroprimed for 4 days (0.0564). At 180 DAT, seedlings hydroprimed for 3 days (0.874) recorded the highest root : shoot ratio and the seeds hydroprimed for 4 days (0.0966) recorded the lowest root : shoot ratio .The largest vigour index at 30 DAT was shown in for 8 days (1016) and the lowest was shown in seeds hydroprimed for 4 days (177). At 180 DAT, seeds hydroprimed for 8 days (1681) recorded the highest vigour index and the seeds hydroprimed for 4 days (313) recorded the lowest vigour index.

Table 48 Effect of hydropriming at various durations on growth indices, root: shoot ratio and vigour indices of sandal seedlings at 30 and 180 days after transplanting for the seeds subjected to post priming storage of one week.

Hydropriming (Days)	Leaf Area Ratio ($cm^2 g^{-1}$)		Leaf Weight Ratio		Root : Shoot Ratio		Vigour index	
	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT	30 DAT	180 DAT
1	3.69^{ab}	18.26^{a}	0.435^{a}	0.476^{a}	0.280^{a}	0.729^{ab}	645^{bc}	999^{bc}
2	10.32^{b}	10.59^{abc}	0.486^{a}	0.517^{a}	0.303^{a}	0.458^{ab}	184^{a}	338^{a}
3	5.90^{ab}	12.73^{abc}	0.452^{a}	0.499^{a}	0.279^{a}	0.878^{b}	304^{ab}	663^{ab}
4	3.85^{ab}	4.36^{ab}	0.833^{b}	0.856^{b}	0.056^{a}	0.097^{a}	177^{a}	313^{a}
6	1.94^{a}	2.67^{a}	0.765^{ab}	0.795^{ab}	0.1068^{a}	0.1579^{ab}	694^{c}	1070^{c}
Values within the same column with similar superscripts are homogenous.								

4.7. Hierarchical cluster analysis

4.7.1. Growth at 30 DAT of the seedlings obtained from seeds stored for one day after priming

Cluster analysis revealed 16 clusters and dendrogram is given in Fig 19. At 30 DAT, the cluster with maximum value was Cluster IX (6 treatments). The Cluster with minimum value is Cluster I (7 treatments). The cluster with maximum number of treatments falls in Cluster IV and Cluster XVI (11 treatments). The cluster with minimum number of treatments falls in Cluster II and Cluster XIII (one treatment). The details of cluster is given in Table 49.

In order to determine the best performing priming method, the cluster were further grouped. For the seeds subjected to post priming storage for one day ,the clustering at 50% level group the treatments to two homogenous clusters , one with minimum value for the growth attributes (Treatments2,3,6,11,12,17,22,30,39,50,54,57and75) and other with maximum value including the rest of the treatment leading to the elimination of clusters with minimum value. At 40 % level the treatments gave two clusters, one with minimum growth attributes (58, 63-74 and 76-78) and other with maximum value. At 20% also the superior cluster was divided into 2 homogenous clusters and within which the treatments 28,29,31,32,25,26,33-38,41-49,51 and 56 lies in cluster with maximum value . Clustering at 10% level leads to formation of 3 clusters which include one with maximum growth attributes (28). Hence, it can be concluded that, the best performance of the seedling is obtained at treatment 28, i.e. biopriming with *Trichoderma viride* at 25% concentration for 4 days for the growth period of 30 days.

Table 49 Clusters of seedling growth attributes of sandal during cluster analysis at 30 days after transplanting for the seeds subjected to post priming storage of one day

Cluster Number	Treatments
Cluster I	Biopriming with *Pseudomonas fluorescens* at 100% for 4 days, Biopriming with *P. fluorescens* at 75% for 6 days, Biopriming with *P. fluorescens* at 50% for 6 days, Biopriming with *P. fluorescens* at 50% for 8 days, Biopriming with *P. fluorescens* at 25% for 8 days, Biopriming with *P. fluorescens* at 25% for 3 days, Biopriming with *P. fluorescens* at 25% for 2 days.
Cluster II	Hydropriming for 3 days
Cluster III	Biopriming with PGPR II at 25% for 2 days, Biopriming with PGPR II at 25% for 8 days, Biopriming with PGPR II at 50% for 3 days
Cluster IV	Biopriming with *Trichoderma viride* at 25% for 8 days , Biopriming with *T. viride* at 75% for 8 days
Cluster V	Biopriming with *T. viride* at 100 % for 6 days , Biopriming with PGPR II at 25% for 4 days , Biopriming with PGPR II at 25% for 6 days, Biopriming with PGPR II at 50% for 6 days, Biopriming with PGPR II at 50% for 8 days, Biopriming with PGPR II at 75% for 2 days
Cluster VI	Hydropriming for 1 days, Biopriming with PGPR II at 100% for 6 days , Hydropriming for 2 days , Hydropriming for 4 days , Hydropriming for 6 days , Biopriming with PGPR II at 100% for 4 days, Biopriming with PGPR II at 100% for 1 day, Biopriming with PGPR II at 75% for 6 days, Biopriming with PGPR II at 75% for 8 days, Biopriming with PGPR II at 75% for 3 days,
Cluster VII	Hydropriming for 8 days , Biopriming with PGPR II at 100% for 3 days
Cluster VIII	Biopriming with PGPR II at 100% for 2 days, Biopriming with PGPR II at 75% for 4 days, Biopriming with PGPR II at 75% for 1 day, Biopriming with PGPR II at 50% for 4 days
Cluster IX	Biopriming with *T. viride* at 25% for 4 days , Biopriming with *T. viride* at 50% for 1 day, Biopriming with *T. viride* at 25% for 6 days , Biopriming with *T. viride* at 50% for 2 days, Biopriming with *T. viride* at 25% for 1 day, Biopriming with *T. viride* at 25% for 2 days
Cluster X	Biopriming with *T. viride* at 75% for 8 days, Biopriming with *T. viride* at 50% for 8 days, Biopriming with *T. viride* at 75% for 1 day, Biopriming with *T. viride* at 75% for 2 days, Biopriming with *T. viride* at 50% for 3 days, Biopriming with *T. viride* at 50% for 6 days
Cluster XI	Biopriming with *T. viride* at 75% for 4 days, Biopriming with *T. viride* at 100% for 3 days
Cluster XII	Biopriming with *T. viride* at 100% for 2 days, Biopriming with *T. viride* at 100% for 8 days, Biopriming with *T. viride* for 100% at 4 days, Biopriming with *T. viride* at 75% for 6 days, Biopriming with *T. viride* at 100% for 1 day, Biopriming with PGPR II at 25% for 1 day, Biopriming with PGPR II at 50 % 1 day , Biopriming with PGPR II at 50% for 2 days, Biopriming with PGPR II at 25% for 3 days

Cluster XIII	Biopriming with *P. fluorescens* at 25% for 1 day
Cluster XIV	Biopriming with *P. fluorescens* at 50% for 1 day , Biopriming with *P. fluorescens* at 75 % for 1 day
Cluster XV	Biopriming with *P. fluorescens* at 25% for 4 days , Biopriming with *P. fluorescens* at 50% for 3 days , Biopriming with *P. fluorescens* at 75% for 2 days , Biopriming with *P. fluorescens* at 25% for 6 days
Cluster XVI	Biopriming with *T. viride* at 25% for 3 days, Biopriming with *P. fluorescens* at 100 % for 6 days , Biopriming with *P. fluorescens* at 100% for 1 day , Biopriming with *P. fluorescens* at 100% for 2 days , Biopriming with *P. fluorescens* at 100% for 3 days , Biopriming with *P. fluorescens* at 50% for 2 days , Biopriming with *P. fluorescens* at 50% for 4 days Biopriming with *P. fluorescens* at 75% for 4 days , Biopriming with *P. fluorescens* at 75% for 3 days , Biopriming with *P. fluorescens* at 75% for 8 days

4.7.2. Growth at 180 DAT of the seedlings obtained from seeds stored for one day after priming

Cluster analysis was conducted and dendrogram is presented in Fig 20. At 180 DAT, the cluster with maximum value was Cluster IX (6 treatments).The Cluster with minimum value was Cluster I (7 treatments). The cluster with maximum number of treatments falls in Cluster XIV (12 treatments). The cluster with minimum number of treatments fall in Cluster II (one treatment).The treatments belonging to different clusters are given in Table 50.

At 180 DAT, clustering at 40 % level leads to formation of two homogenous clusters, one with maximum value (Treatment 25 to treatment 76, except treatment 27) and other with minimum value (Treatment 1-24 and treatment 27). At 30 % level lead to the formation of 3 cluster segments, within which the treatments 25, 26, 28, 29, 31-38, and 42 lies in the cluster with maximum value. At 20 % level, the cluster with maximum value is separated (treatment 25,26,28,29 and 31-32). At 10 % level leads 2 clusters were obtained, the one with maximum value is cluster with treatment 28 and all other treatments falls in the cluster with minimum value, which leads to the conclusion that the best performance of the seedling on biopriming with *Trichoderma viride* at 25% for 4 days is carried over up to 180 DAT also.

Table 50 Clusters of seedling growth attributes of sandal during cluster analysis at 180 days after transplanting for the seeds subjected to post priming storage of one day

Cluster Number	Treatment
Cluster I	Biopriming with *Pseudomonas fluorescens* at 75 % for 6 days , Biopriming with *P. fluorescens* at 100% for 3 days , Biopriming with *P. fluorescens* at 50% for 6 days , Biopriming with *P. fluorescens* at 50% for 8 days, Biopriming with *P. fluorescens* at 25% for 2 days , Biopriming with *P. fluorescens* at 25% for 3 days , Biopriming with *P. fluorescens* at 25% for 8 days
Cluster II	Biopriming with *P. fluorescens* at 25% for 1 day
Cluster III	Biopriming with *P. fluorescens* at 50% for 1 day , Biopriming with *P. fluorescens* at 50% for 8 days
Cluster IV	Biopriming with *P. fluorescens* at 50% for 4 days , Biopriming with *P. fluorescens* at 75% for 2 days , Biopriming with *P. fluorescens* at 25% for 4 days , Biopriming with *P. fluorescens* at 25% for 6 days
Cluster V	Biopriming with *T. viride* at 25% for 3 days , Biopriming with *P. fluorescens* at 100% for 1 day , Biopriming with *P. fluorescens* at 100% for 2 days, Biopriming with *P. fluorescens* at 100% for 8 days , Biopriming with *P. fluorescens* at 50% for 2 days , Biopriming with *P. fluorescens* at 50% for 4 days , Biopriming with *P. fluorescens* at 75 % for 3 days , Biopriming with *P. fluorescens* at 75 % for 3 days , Biopriming with *P. fluorescens* at 75 % for 8 days
Cluster VI	Hydropriming for 3 days
Cluster VII	Biopriming with PGPR II at 25% for 2 days , Biopriming with PGPR II at 25% for 8 days , Biopriming with PGPR II at 50% for 3 days
Cluster VIII	Biopriming with *T. viride* at 25% for 8 days , Biopriming with *T. viride* at75% for 3 days
Cluster IX	Biopriming with *T. viride* at 25% for 4 days , Biopriming with *T. viride* at 25% for 6 days , Biopriming with *Trichoderma viride* at 50% for 1 day, Biopriming with *T. viride* at 50% for 2 days, Biopriming with *T. viride* at 25% for 1 day, Biopriming with *T. viride* at 25% for 2 days
Cluster X	Biopriming with *T. viride* at 75% for 8 days, Biopriming with *T. viride* at 50% for 8 days, Biopriming with *Trichoderma viride* at 75% for 1 day, Biopriming with *T. viride* at 75% for 2 days, Biopriming with *T. viride* at 50% for 3 days,

	Biopriming with *T. viride* at 50% for 4 days, Biopriming with *T. viride* at 50% for 6 days.
Cluster XI	Biopriming with *T. viride* at 75% for 4 days , Biopriming with *T. viride* at 100% for 3 days
Cluster XII	Biopriming with *T. viride* at 100% for 2 days , Biopriming with *T. viride* at 100% for 8 days , Biopriming with *Trichoderma viride* at 100% for 4 days, Biopriming with *T. viride* at 75% for 6 days , Biopriming with *T. viride* at 100% for 1day, Biopriming with PGPR II at 25% for 1 day, Biopriming with PGPR II at 25% for 3 days , Biopriming with PGPR II at 50% for 2 days, Biopriming with PGPR II at 50% for 1 day
Cluster XIII	Biopriming with PGPR II at 50% for 8 days , Biopriming with PGPR II at 75% for 2 days, Biopriming with PGPR II at 25% for 4 days, Biopriming with PGPR II at 25% at6 days, Biopriming with *T. viride* at 100% for 6 days .
Cluster XIV	Biopriming with PGPR II at 50% for 6 days, Biopriming with PGPR II at 100 % for 1 day , Biopriming with PGPR II at 100% for 4 days , Biopriming with PGPR II at 75 % for 4 days , Biopriming with PGPR II at 75% for 6 days , Biopriming with PGPR II at 100% for 6 days , Biopriming with PGPR II at 100% for 8 days , Hydropriming for 1 day, Hydropriming for 2 days , Hydropriming for 4 days
Cluster XV	Hydropriming for 8 days , Biopriming with PGPR II at100% for 3 days
Cluster XVI	Biopriming with PGPR II at 50% for 4 days , Biopriming with PGPR II at75% for 1 day, Biopriming with PGPR II at75% for 4 days , Biopriming with PGPR II at100% for 2 days

4.7.3. Growth at 30 DAT of the seedlings obtained from seeds stored for one week after priming

Cluster analysis was conducted and dendrogram is presented in Fig 21. Hierarchical cluster analysis indicated that the cluster with maximum value is Cluster XV (one treatment). The Cluster with minimum value is Cluster I (4 treatments), Cluster II (5 treatments), Cluster III (2 treatments) and Cluster IV (2 treatments).The cluster with maximum number of treatments falls in Cluster X and Cluster XIV (15 treatments). The cluster with minimum number of treatments fall in Cluster VI, Cluster VIII, Cluster XI, and Cluster XV (one treatment). The treatment with zero values falls in Cluster I (4 treatments), Cluster II (5 treatments), Cluster III (2 treatments) and Cluster IV (2 treatments).

At 30 DAT, for the seeds subjected to post priming storage for one week, were further grouped to find best treatment, at 50% level, two homogenous clusters, the one with minimum value (Treatments 1,3,27,29,47-49,39,54,60,65,66 and 70) which was excluded in the next stage and others with maximum growth attributes (rest of the treatment) was obtained. At 40 % level, two homogenous clusters were formed within the superior cluster, one with minimum value (71-78, 61-64, 50-53, 67-69 and 55-59) and rest of the treatments in second cluster. Clustering superior cluster at 20 % level, led to formation two clusters, one with minimum value i.e. treatments 26, 28, 30-35 and 40-46 and rest of the treatments in second cluster. At 10 % level, this superior cluster was divided into 4 homogenous clusters and the cluster with maximum value comprises the treatment 24, which leads to the conclusion that the best seedling performance is on biopriming the seeds with *Pseudomonas fluorescens* at 100% for 8 days.

Table 51 Clusters of seedling growth attributes of sandal during cluster analysis at 30 days after transplanting for the seeds subjected to post priming storage of one week

Cluster Number	Treatments
Cluster I	Biopriming with PGPR II at 50% for 8 days , Biopriming with PGPR II at 75% for 6 days , Biopriming with PGPR II at 75 % for 8 days , Biopriming with PGPR II at 100% for 4 days
Cluster II	Biopriming with *T. viride* at 75% at 3 days , Biopriming with PGPR II at 25% for 8 days , Biopriming with PGPR II at 25% for 1 day , Biopriming with *T. viride* at 100% for 6 days , Biopriming with *T. viride* at 100% for 8 days
Cluster III	Biopriming with *P. fluorescens* at 25% for 1 day , Biopriming with *P. fluorescens* at 25% for 3 days
Cluster IV	Biopriming with *T. viride* at 25% for 3 days , Biopriming with *T. viride* at 25% for 6 days
Cluster V	Biopriming with PGPR II at 25 for 2 days , Biopriming with PGPR II at 25 % for 3 days , Biopriming with PGPR II at 25 % for 4 days , Biopriming with PGPR II at 25 % for 6 days , Biopriming with PGPR II at 50% for 2 days ,Biopriming with PGPR II at 50% for 1 day , Biopriming with PGPR II at 75% for 1 day .
Cluster VI	Biopriming with PGPR II at 100% for 6 days
Cluster VII	Biopriming with PGPR II at 50 % 3 days , Biopriming with PGPR II for 50% for 6 days
Cluster VIII	Biopriming with PGPR II at 100% for 3days
Cluster IX	Biopriming with PGPR II at 50% for 4 days , Biopriming with PGPR II 75 % at 2 days , Biopriming with PGPR II at 75% for 3 days , Biopriming with PGPR II at 75% for 4 days , Biopriming with PGPR II at 100 % for 1 day , Biopriming with PGPR II at 100% for 2 days ,Biopriming with PGPR II at 100% for 8 days , Hydropriming for 1 day, Hydropriming for 2 days, Hydropriming for 3 days , Hydropriming for 4 days , Hydropriming for 6 days , Hydropriming for 8 days
Cluster X	Biopriming with *T. viride* at 100% for 4 days , Biopriming with *T. viride* at 100% for 1 day , Biopriming with *Trichoderma viride* at 75% for 1 day , Biopriming with *T. viride* at 75% for 4 days , Biopriming with *T. viride* at75% for 6 days, Biopriming with *T. viride* at 75% for 8 days , Biopriming with *Trichoderma viride* at 75% for 2days , Biopriming with *T. viride* at 25 % for 2 days , Biopriming with *T. viride* at 25% for 4 days , Biopriming with *T. viride* at 25 % for 8 days ,

	Biopriming with *Trichoderma viride* at 50 % for 1 day , Biopriming with *T. viride* at 50 % for 2 days , Biopriming with *T. viride* at 50 % for 3 days , Biopriming with *T. viride* at 50 % for 4 days , Biopriming with *T. viride* at 50 % for 6 days
Cluster XI	Biopriming with *T. viride* at 50 % for 8 days
Cluster XII	Biopriming with *T. viride* at 100 % for 2 days , Biopriming with *T. viride* at 100% for 3 days
Cluster XIII	Biopriming with *P. fluorescens* at 25% for 2 days, Biopriming with *P. fluorescens* at 25% for 8 days , Biopriming with *P. fluorescens* at 50% for 1 day
Cluster XIV	Biopriming with *P. fluorescens* at 75% for 3 days , Biopriming with *P. fluorescens* at 50% for 6 days , Biopriming with *P. fluorescens* at 50% for 8 days , Biopriming with *P. fluorescens* at 100 % for 3 days, Biopriming with *P. fluorescens* at 75% for 6 days , Biopriming with *P. fluorescens* at 75% for 8 days , Biopriming with *P. fluorescens* at 100% for 1 day, Biopriming with *P. fluorescens* at 25 % for 4 days ,Biopriming with *P. fluorescens* at 25 % for 6 days , Biopriming with *P. fluorescens* at 50 % for 3 days , Biopriming with *P. fluorescens* at 50% for 4 days , Biopriming with *P. fluorescens* at 75% for 1 day. Biopriming with *P. fluorescens* at 75% for 2 days , Biopriming with *P. fluorescens* at 75% for 4 days
Cluster XV	Biopriming with *P. fluorescens* at 100 % for 8 days
Cluster XVI	Biopriming with *P. fluorescens* at 100 % for 2 days , Biopriming with *P. fluorescens* at 100 % for 4 days , Biopriming with *P. fluorescens* at 100% for 6 days , Biopriming with *T. viride* at 25% for 1 day

4.7.4. Growth at 180 DAT of the seedlings obtained from seeds stored for one week after priming

Cluster analysis was conducted and dendrogram is presented in Fig 22. At 180 DAT, for seeds stored for one week, the cluster with maximum value is Cluster XIII (1 treatment). The Cluster with minimum value is Cluster I, Cluster II, Cluster XV and Cluster XVI. The cluster with maximum number of treatments falls in Cluster XI (16 treatments). The cluster with minimum number of treatments fall in Cluster XIII and Cluster XII (2 treatments) .The treatment with zero values falls in Cluster I , Cluster II, Cluster XV and Cluster XVI . .

During 180 DAT, clustering at 40 % level two homogenous clusters were obtained in which one was with maximum and another with minimum value i.e. treatments 37-76 and 26-35 which were eliminated in the next level. At 30% level, again two homogenous clusters were obtained, the one with maximum value and another with minimum value i.e. treatments 1,3,27 and 29 and those were eliminated. At 20 % level, 4 homogenous clusters are obtained, of which the cluster with maximum value lies with the treatments 22, 23, 24, 25 and 36. Clustering this at 10 % level gave three homogenous clusters and the cluster with maximum value comprises treatment 24, which leads to the conclusion that the best seedling performance is obtained on biopriming with *Pseudomonas fluorescens* at 100% for 8 days (Treatment 24).

Table 52 Clusters of seedling growth attributes of sandal during cluster analysis at 180 days after transplanting for the seeds subjected to post priming storage of one week

Cluster Number	Treatments
Cluster I	Biopriming with PGPR II at 50% for 8 days , Biopriming with PGPR II at 75% for 6 days , Biopriming with PGPR II at 75% for 8days , Biopriming with PGPR II at 100% for 4 days
Cluster II	Biopriming with *T. viride* at 75% for 3 days , Biopriming with PGPR II at 25% for 8 days , Biopriming with *T. viride* at 100 % for 6 days , Biopriming with *T. viride* at 100 % for 8 days , Biopriming with PGPR II at 25% for 1 day
Cluster III	Biopriming with PGPR II at 100 % for 6 days , Biopriming with PGPR II at 100 % for 8 days , Hydropriming for 1 day , Hydropriming for 4 days , Hydropriming for 6 days , Hydropriming for 8 days
Cluster IV	Hydropriming for 2 days , Hydropriming for 3 days , Biopriming with PGPR II at 50% for 4 days , Biopriming with PGPR II at 75% for 2 days ,Biopriming with PGPR II at 75% for 3 days, Biopriming with PGPR II at 75% for 4 days, Biopriming with PGPR II at 100% for 1 day, Biopriming with PGPR II at 100% for 2 days, Biopriming with PGPR II at 100% for 3 days
Cluster V	Biopriming with *T. viride* at 100% for 2 days , Biopriming with *T. viride* at 100 % for 3 days
Cluster VI	Biopriming with PGPR II at 50 % for 3 days, Biopriming with PGPR II at 50% for 6 days.
Cluster VII	Biopriming with *T. viride* at 25 % for 4 days , Biopriming with *T. viride* at 25% for 8 days , Biopriming with *Trichoderma viride* at 50% for 1 day ,Biopriming with *T. viride* at 50% for 1 day , Biopriming with *T. viride* at 50% for 2 days , Biopriming with *T. viride* at 50% for 3 days , Biopriming with *T. viride* at 50% for 4 days , Biopriming with *T. viride* at 50% for 6 days ,Biopriming with *T. viride* at 75% for 1 day , Biopriming with *T. viride* at 75% for 2 days , Biopriming with *T. viride* at 75% for 4 days , Biopriming with *Trichoderma viride* at 75% for 8 days , Biopriming with *T. viride* at 75% for 6 days , Biopriming with *Trichoderma viride* at 100 % for 1 day, Biopriming with *T. viride* at 100 % for 4 days
Cluster VIII	Biopriming with PGPR II at 75% for 1 day , Biopriming with PGPR II at 50% for 1 day, Biopriming with PGPR II at 50% for 2 days
Cluster IX	Biopriming with PGPR II at 25% for 2 days , Biopriming with PGPR II at 25% for 3 days , Biopriming with PGPR II at 25% for 4 days , Biopriming with PGPR II at 25% for 6 days

Cluster X	Biopriming with *P. fluorescens* at 25% for 2 days , Biopriming with *P. fluorescens* at 25 % for 8 days , Biopriming with *P. fluorescens* at 50% for 1 day , Biopriming with *P. fluorescens* at 50% for 3 days
Cluster XI	Biopriming with *P. fluorescens* at 25% for 4 days , Biopriming with *P. fluorescens* at 25% for 6 days , Biopriming with *P. fluorescens* at 50% for 2 days , Biopriming with *P. fluorescens* at 50% for 6 days , Biopriming with *P. fluorescens* at 50% for 8 days , Biopriming with *P. fluorescens* at 75% for 1 day , Biopriming with *P. fluorescens* at 75% for 2 days , Biopriming with *P. fluorescens* at 75% for 3 days , Biopriming with *P. fluorescens* at 75% for 4 days , Biopriming with *P. fluorescens* at 75% for 6 days , Biopriming with *P. fluorescens* at 75% for 8 days ,Biopriming with *P. fluorescens* at 100% for 1 day , Biopriming with *P. fluorescens* at 100% for 2 days , Biopriming *with P. fluorescens* at 100% for 3 days ,Biopriming with *P. fluorescens* at 25% for 2 days
Cluster XII	Biopriming with *T. viride* at 50% for 8 days
Cluster XIII	Biopriming with *P. fluorescens* at 100% for 8 days
Cluster XIV	Biopriming with *P. fluorescens* at 100% for 4 days , Biopriming with *P. fluorescens* at 100% for 6 days ,Biopriming with *T. viride* at 25 % for 1 day
Cluster XV	Biopriming with *P. fluorescens* at 25 % for 1 day , Biopriming with *P. fluorescens* at 25 % for 3 days ,
Cluster XVI	Biopriming with *T. viride* at 25 % for 3 days , Biopriming with *T. viride* at 25 % for 6 days

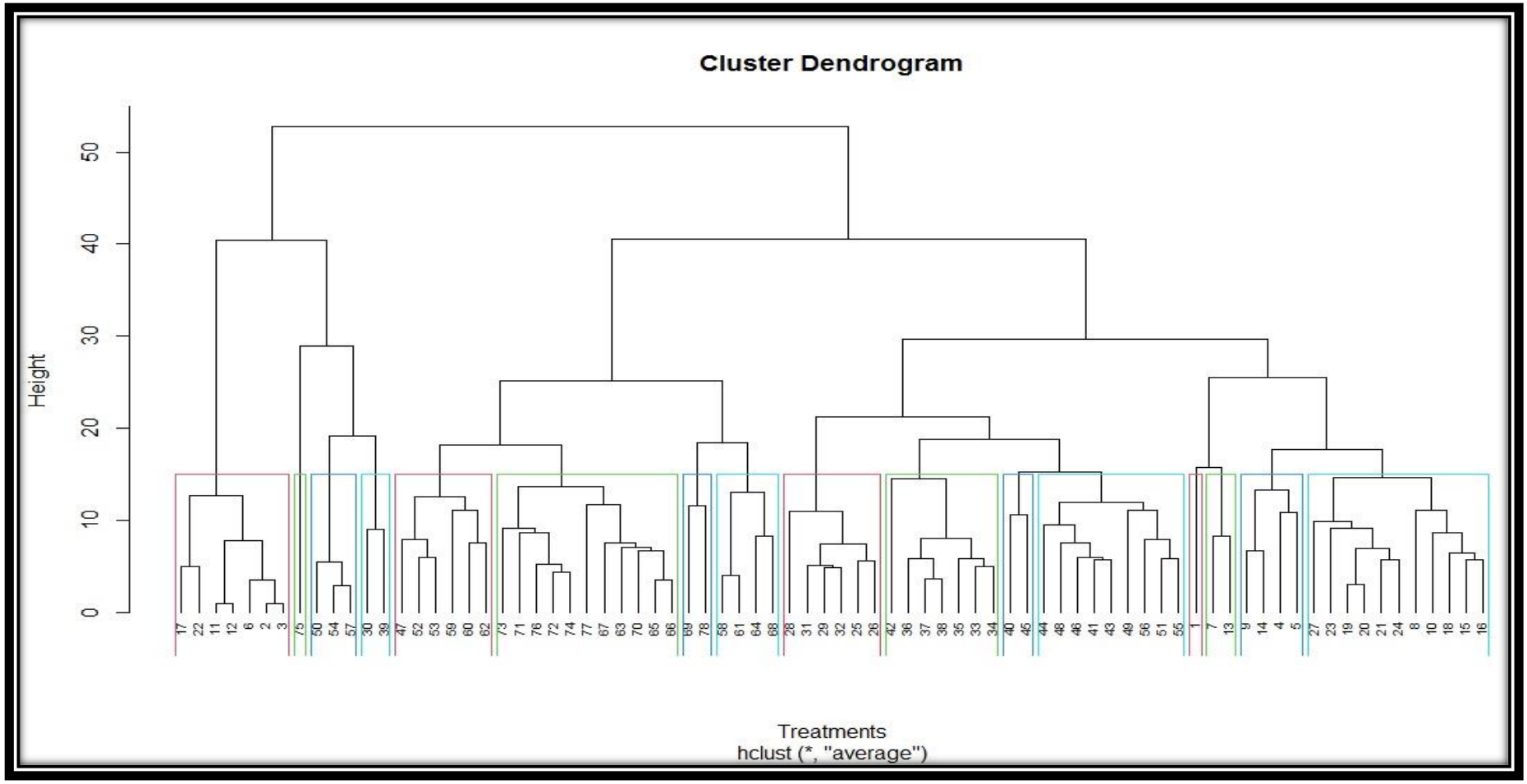

Fig 19 Dendrogram presenting the clustering pattern of seed priming treatments based on seedling performance at 30 days after transplanting for the seeds subjected to post priming storage for one day

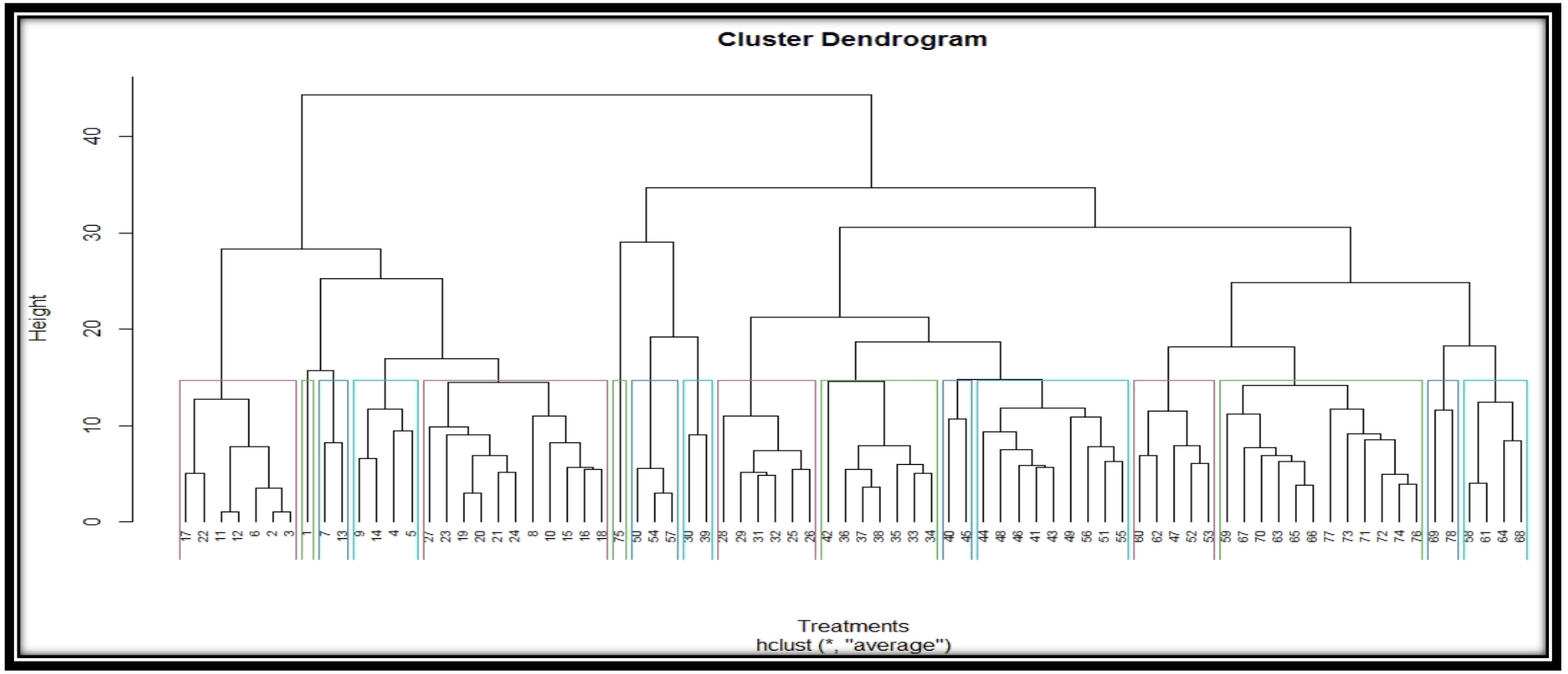

Fig 20 Dendrogram presenting the clustering pattern of seed priming treatments based on seedling performance at 180 days after transplanting for the seeds subjected to post priming storage for one day

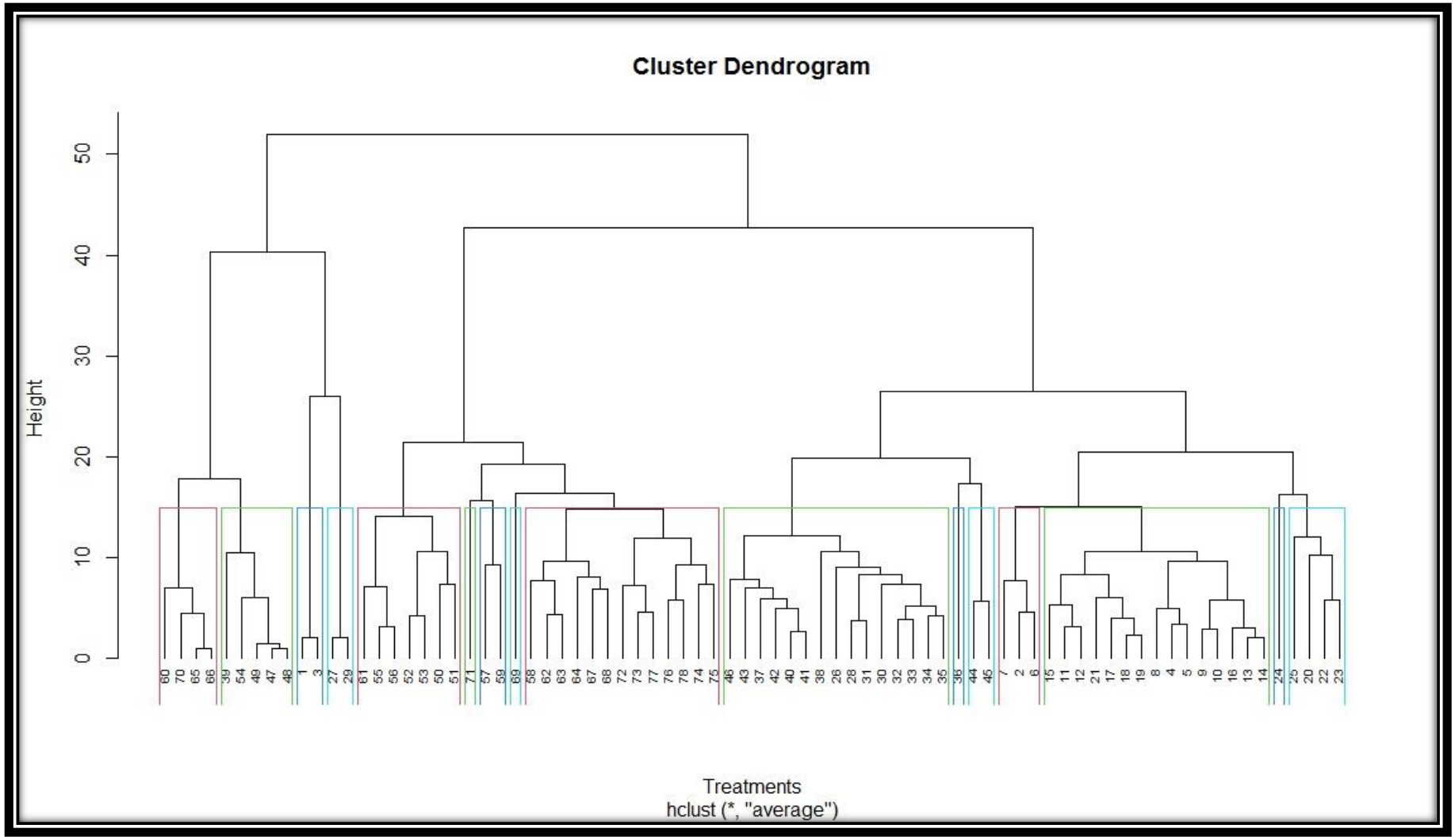

Fig 21 Dendrogram presenting the clustering pattern of seed priming treatments based on seedling performance at 30 days after transplanting for the seeds subjected to post priming storage for one week

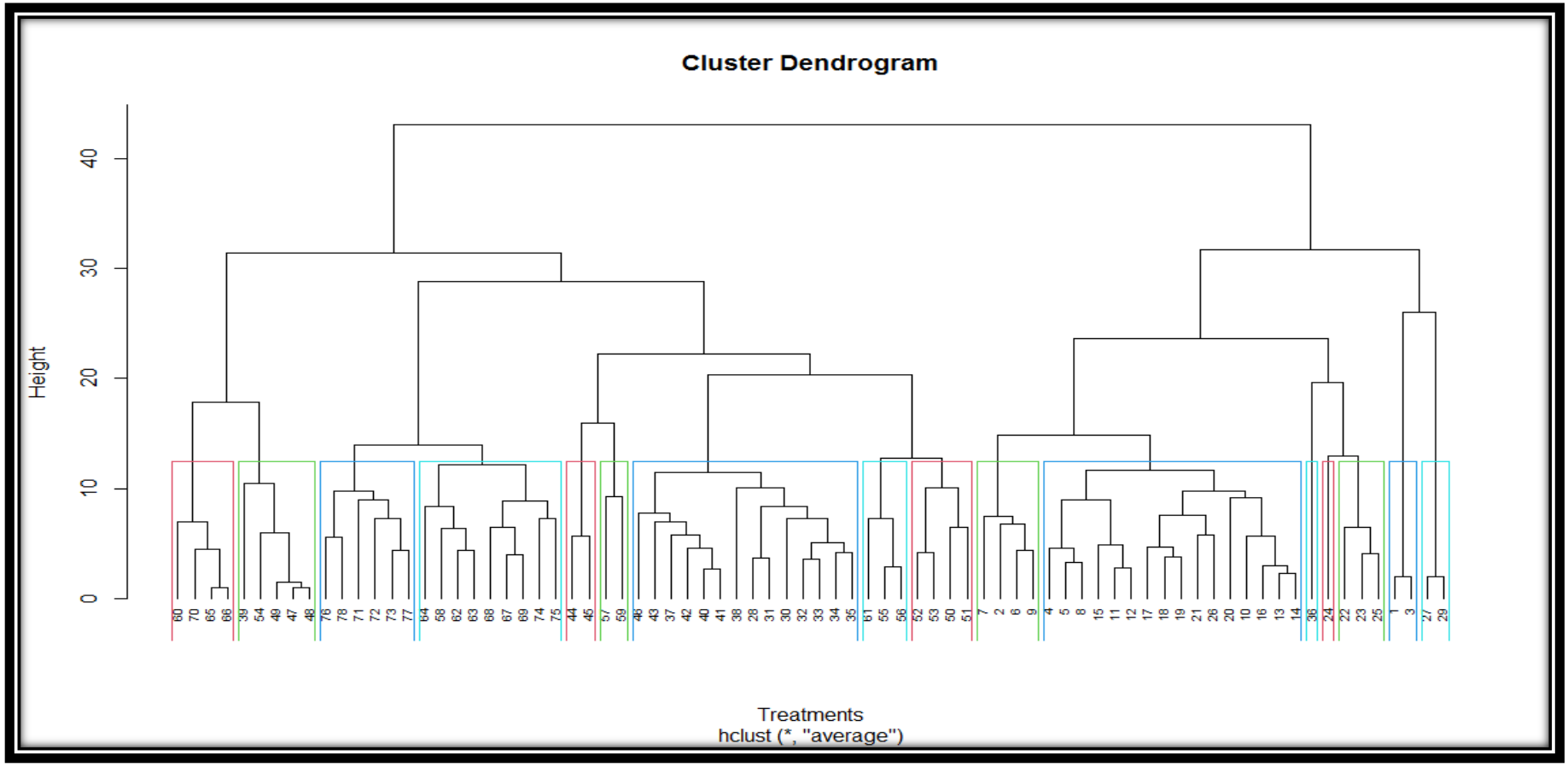

Fig 22 Dendrogram presenting the clustering pattern of seed priming treatments based on seedling performance at 180 days after transplanting for the seeds subjected to post priming storage for one week

Discussion

The present investigation was carried out to find the effect of biopriming techniques on the seed germination and seedling attributes of Sandal (*Santalum album*, L.). The results of the study are discussed in the following sections.

5.1. Impact of priming techniques on germination attributes of Sandal

Seed priming initiates the essential metabolic processes favouring the enhanced seed germination. Rapid, efficient and uniform seed germination is important in crop propagation. Biopriming is the treatment of seeds with beneficial microorganisms under controlled hydration which enhances the preparatory processes prior to germination without radicle emergence. The unique achievements of the primed seeds includes, increased germination rate, greater uniform germination, and greater total germination percentage (Barsa *et al.,* 2005). Increased germination rate and uniformity is attributed to metabolic repair during imbibition (Bray *et al.,* 1989), enhancement of germination promoting metabolites (Barsa *et al.,*2005) ,osmotic adjustments (Bradford,1986) and for seeds that are not re-dried after treatment ,a simple reduction in lag time of inhibitions (Bradford,1986). Perusal of literature indicated that the seeds of forest crops are primed for a longer duration up to two weeks (Schmidt, 2000; Adebisi *et al*., 2013) The study conducted at College of Forestry, by Chitra (2019) with higher duration of priming agents like water, $MnSO_4$, PEG 6000 and *P. fluorescens* in different concentration indicated that higher duration of treatment and post- priming storage for one day was the best in terms of germination and seedling attributes. The study also indicated that the post priming storage of seeds for one month failed to germinate. The biopriming treatments were superior to other priming methods hence, the current study focuses on biopriming at lower duration of the treatment and a lower post priming storage of one week. The stages of seed germination is depicted in Plate 2.

With regard to of seeds bioprimed with *Pseudomonas fluorescens*, the maximum germination was obtained for the seeds treated at 25% for 3 days (34.609%) and the minimum was on priming at 50% concentration for 2 days (0.00%) for the seeds with a post priming storage period of one day. The Mean Daily Germination (MDG), Plant Value (PV) and Germination Value (GV) were highest for biopriming for 25% for 4 days (4.00, 3.06 and 12.24 respectively) and the minimum 75% for 1 day (0.04, 0.09 and 0.0036 respectively). For one week storage, the highest germination was obtained for the seeds that were subjected to biopriming at 100% for 6 days (81.264%) and the lowest was obtained for the seeds subjected to biopriming at 25 % for 3 days (8%). The MDG, PV and GV were highest for biopriming for 50% for 6 days (4.288, 4.742 and 23.156 respectively) and the minimum 50 % for 1day (0.734, 0.82, and 0.61 respectively).The best germination observed during one day storage was only 34.6% but it almost doubled during one week storage. The results of biopriming *P. fluorescens* demonstrated that it can increase the germination percent of sandal seeds, and the study is in conformity with a similar results on biopriming of *Abies hickelii* seeds with *P. fluorescens* which increased the germination percent by 91% compare to the control. (Rodriguez *et al.,* 2015). The strains of *Pseudomonas fluorescens* can produce several plant growth regulating phytohormones, including IAA (indole – 3 acetic acid) (Jeon *et al*., 2003). Chitra (2019) also reported the superiority of biopriming treatments in sandal (88% germination with 100% concentration bioinoculant for 8 days).

The results on biopriming with *Trichoderma viride* demonstrated that the , the highest germination percentage was obtained for the seeds treated at 100 % concentration for 1 day (73.3%) and the lowest in biopriming at 25% for 8 days (2.61%) for the post priming storage of one day. The MDG, PV and GV were highest for biopriming for 25% for 4 days (4.91, 3.72, and 18.28 respectively) and the lowest was for 50 % for 2 days. (0.4, 0.27 and 0.11, respectively. For the post priming storage of one week, the seeds treated at 100% for 3 days recorded the maximum germination (82.72%) the lowest at 100 % for 6 days (1.22%).The MDG, PV and GV were highest for biopriming for 50% for 3 days (5.736, 6.411 and 36.78 respectively) and obtained minimum for 100% for 8 days (0.371, 0.49 and 0.18221 respectively). There was no such striking improvement in the seed germination after the post priming storage of one week. *Trichoderma* spp. was recently suggested as a Plant Growth Promoting Fungi (PGPF) due to their ability to produce siderophore, phosphate-solubilizing enzymes, and phytohormones (Doni *et al.,* 2013). Trichoderma induces the plant IAA production and improve seedling quality (Gravel *et al.,* 2006). Doni *et al* (2014) reported that Trichoderma spp. have been proven to induce positive plant growth promotion potential in enhancing the rice seed germination and vigour (Doni *et al.,* 2014) and in Capsicum also the *T.viride* enhanced the germination percentage (Ananthi *et al*., 2014)

Another promising finding was that biopriming with PGPR II also influence the germination of sandal seeds and the maximum germination was obtained for the seeds that are treated at 75 % for a duration of 6 days (29.36%) and the lowest value was obtained in biopriming at 50% for 3 days (1.22%). The MDG, PV and GV were highest for biopriming for 25% for 2 days (4.55, 3.41 and 15.56, respectively) and the minimum for 50% for 1 day (1, 0.25 and 0.25, respectively). For the post priming storage of one week, the maximum germination is obtained at 50% for 3 days (76.6%) and the lowest was obtained for the seeds subjected to biopriming at 100% for 3 days and for 25 % for 1 day (0%). The MDG, PV and GV were highest for biopriming for 25% for 3 days (6.76, 6.57 and 44.45, respectively) and the minimum for 25% for 1 day and 100% for 3 days. The PGPR II also showed the similar trend with regard to post priming storage and storage for one week could result in 2.53 times increase in the maximum germination. PGPR are a group of functional bacteria that have the ability as a growth promoter, the process occurs by synthesising and regulating the concentrations of various growth regulator or plant growth regulator such as IAA (Patten and Glick, 2002).

From the results, it is clear that biopriming significantly increased germination of the sandal seeds. Both exogenous and endogenous IAA inhibit seed germination assayed by radicle protrusion, in an ABA depended manner, indicating that auxin acts synergistically to inhibit seed germination. (Liu *et al.,*2013) which may be the basic mechanism behind biopriming, on removal of stress conditions and pre-treating with GA 3 which acts antagonistic to ABA (Weiss and Ori ,2007) which breaks dormancy may leads to the germination of seedlings. Soaking of seeds in bacterial suspension initiates the physiological processes in the seed where plumule and radicle emergence is prevented until the seed have temperature and oxygen after being sown. (Anitha *et al*., 2013). The increase in germination of the bioprimed seeds can be attributed to synthesis of plant or tree growth hormones, enhancement of nutrient availability, and provision of biological control attributable to fructification of antibiotics or siderophores (Deepa *et al.,* 2010).

The results on hydropriming indicated that the maximum value of germination was obtained for the duration of for 2 days (30.13%) and the lowest was obtained for hydropriming for 1 day (6.39%) for one day storage .The MDG, PV and GV were highest for 6 days duration (3.11, 2.00 and 6.22, respectively) and the

lowest for 4 days duration (2.00, 0.52 and 1.04, respectively). For one week, the maximum germination percentage is obtained at 8 days (56%) and the lowest was obtained for the seeds subjected to hydropriming for 4 days (10.62%). The MDG, PV and GV were highest for 6 day (3.38, 2.84, and 9.61, respectively) and the minimum for hydropriming for 2 days. (0.78, 0.878 and 0.6871, respectively). Post priming storage of the seeds also could double the maximum germination compared to one day storage. Hydropriming increases activities of antioxidant enzymes like superoxide dismutase, peroxidase, and catalase and ascorbate peroxidase. (Huang *et al.,* 2006). The improvement in germination could largely depend upon the activities of antioxidant enzymes (Ahmed *et al.*, 2012). In fact, increased level of antioxidant enzymes protects the cell against oxidative damage by removal of free radicals or reactive oxygen species (Ahmed *et al.*, 2012). The germination trial indicated that all the biopriming treatments can enhance the germination of sandal seeds compared to hydropriming and the maximum germination obtained during the investigation was 81.26% on priming with *P. fluorescens*, 82.72% in *T. viride*, 76.6% in PGPR II and 56% in hydropriming. During priming with *P. fluorescens* with post priming storage for one day the imbibition period was reduced to 13 days and the maximum germination period was reduced to 22 days. However, the treatment with highest germination had an imbibition period of 22 days and germination period of 49 days. Whereas, at one week storage, the imbibition and germination period was 15 and 28 days respectively. In the best germinating treatment with *T. viride*, the imbibition and germination period was 19 and 28 days at one day post priming storage and was 21 and 52 days at one week storage. The treating with PGPR II also resulted in the lower imbibition and germination period for the best treatment with one day storage i.e.18 and 35 days respectively and at one week storage it was 15 and 41 days, respectively. Although germination was lower in hydropriming at one day storage the imbibition and energy period was 21 and 33 days and at one week storage, 15 and 41 days respectively. Sandal seeds takes 2 to 22 weeks (Srimathi *et al.*, 1995; Sutheesh *et al.,* 2016) to complete germination. With the adoption of biopriming and hydropriming the germination period was considerably reduced. Chitra (2019) also reported the similar reduction in germination period due to different priming techniques in sandal.

The post priming storage of seeds showed a sharp increase in the maximum germination of sandal. It is reported that the seed priming reduces the longevity of primed seeds enormously compared with non-primed seeds (Schwember *et al.*, 2005; Hill *et al.,* 2007). Nevertheless, it has been reported that seed priming prior to storage improved the longevity of seeds (Butler *et al.,* 2009). Storage for higher duration like three or six months has decreased the germination in most of the studies. In sandal Chitra (2019) did not get any germination after one month storage. In our results there was an increase of germination by 2.1 times on post priming storage of one week in *P. fluorescens*, 2.53 times in PGPR II and 1.93 times in hydropriming and the change in germination due to *T. viride* was the least. Hence, further trials are needed to standardise the post priming storage duration. Mc Donald (1999) reported better storability of primed seeds owing to reversal of seed deterioration. Gurusinghe *et al.* (2002) reported that when primed seeds are slowly dried back, it induces synthesis of LEA (late embryogenesis abundant) proteins, while rapid drying at higher temperatures may induce heat shock proteins, promoting protective mechanisms which increased the seed storage life.

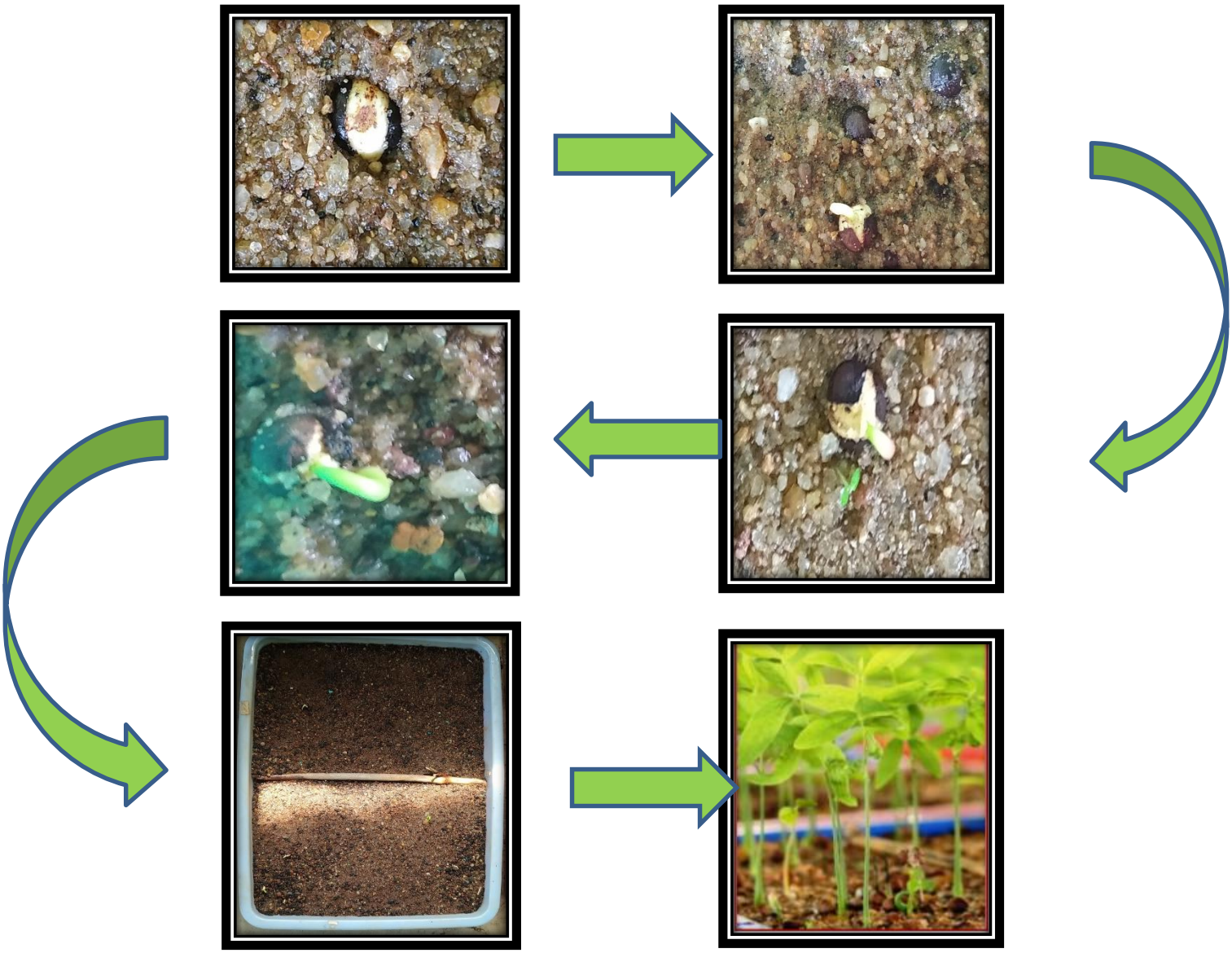

Plate 2 – Stages of seed germination

5.2. Effect of seed biopriming on the electrical conductivity and biochemical composition of the seeds

Electrical conductivity (EC) determines the measures the leakage of the seeds soaked in water (Mathews and Powell, 2006). Decrease in seed germination is an indication of cell membrane deterioration, which in turn accelerates the solute leakage into the medium. Primary objective of priming is to reduce the electrical conductivity of the seed leachates (Perry, 1977). Copeland and Mc Donald (2000) reported that the lower EC of seeds indicate the cell membrane integrity during priming which reduces leakage from the cells.

For the seeds treated with *Pseudomonas fluorescens* the maximum value EC was obtained for seeds treated at 75% for 4 days (1.159 dS cm^{-1}) and the lowest at 25% for 6 days (0.325dS cm^{-1}). For seeds bioprimed with *Trichoderma viride* , the highest value was obtained for seeds bioprimed at 75% for 6 days (1.320 dS cm^{-1}) and the lowest was at 75% for 1day (0.217 dS cm^{-1}). Whereas, in biopriming with PGPR II the maximum EC

was obtained at 25% for 2 days (0.962 dS cm^{-1}) and the minimum at 100% for 1 day (0.247 $dScm^{-1}$). During hydropriming, the highest value of EC was in seeds treated for the duration of 2 days (1.450 $dScm^{-1}$) and the minimum at 6 days (0.153 dS cm^{-1}). For *Pseudomonas fluorescens* the maximum EC conductivity was recorded at for higher concentration and vice versa. For biopriming with *T. viride* the maximum value of electrical conductivity was shown at higher duration and vice versa. In biopriming with PGPR II, the maximum value of electrical conductivity is shown at lower concentration and the minimum value was at higher concentration. For hydropriming, the maximum value is obtained at lower duration and minimum at higher duration .Priming is significant in all cases, where the electrolyte leakage was reduced compared to the untreated seeds which seem due to better membrane repair during the re-drying process following priming. Overall it can be concluded that lower EC was obtained in the priming of seeds with PGPR II compared to other treatments. It is evident that priming process leads to repair mechanism of membrane, enhancing its stability as primed seeds recorded lower electrical conductivity. Gangadharayya *et al.* (2019) also reported the similar results on biopriming with bioinoculants in foxtail millet.

With regard to changes in biochemical constituents of primed seeds, in seeds bioprimed with *P fluorescens*, the maximum carbohydrate content was in biopriming at 100% for 3 days (0.3337mg g^{-1}) and the lowest was at 50% for 6 days (0.0879mg g^{-1}). The value of total protein content falls maximum for the seeds bioprimed at 25% for 6 days (0.062mg g^{-1}) and the minimum at 50% for 1 day (0.016mg g^{-1}). On considering total crude fat content, the maximum value was obtained for seeds bioprimed at 100% for 3 days (73.2%) and the minimum at 100% for 2 days (44.6%). The maximum value of total carbohydrate was obtained for highest concentration and low duration but the minimum value is obtained at lower concentration and high duration. While, for total protein content, the maximum value was obtained for higher duration and *vice versa*. For total crude fat content the maximum and minimum value is obtained both at higher concentration but at different durations.

For seeds bioprimed with *T viride*, the maximum carbohydrate content was obtained for seeds bioprimed at 25% for 3 days (0.722mg g^{-1}) and the minimum at 75% for 2 days (0.110mg g^{-1}). Protein content was the maximum on biopriming at 100% for 1 day (0.051mg g^{-1}) and the lowest at 25% for 1 day (0.020mg g^{-1}). Total crude fat content was maximum at 100% for 6 days (76%) and the minimum at 75% for 1 day (34%). It can be observed that total carbohydrate content of the seeds increased with increase in duration of the treatment. The total protein value was maximum at higher concentration and minimum at lower concentration. The crude fat was maximum at higher duration and minimum at lower duration.

For the seeds bioprimed with PGPR II, the maximum carbohydrate was at 100% for 1 day (0.370mg g^{-1}) and the lowest was for 75% for 4 days (0.127mg g^{-1}). Total protein recorded the highest value at 25% for 4 days (0.077 mg g^{-1}) and the lowest at 75% for 3 days (0.03mg g^{-1}). The crude fat content was maximum value in seed bioprimed at 25% for 2 days (74 %) and the lowest was for 75% for 6 days (44.6%). The results indicate that highest total carbohydrate content is obtained for the seeds subjected to higher concentration but lower duration and the minimum value for the high duration. Total protein content increased with the decrease in concentration. The crude fat is obtained maximum at lowest concentration and duration.

The maximum value for carbohydrate in hydropriming was obtained for the duration of 6 days (0.394mg g^{-1}) and the lowest was for 4 days (0.168mg g^{-1}). The highest value for the total protein content was for duration of 8 days (0.042 mg g^{-1}) and the lowest was for a duration of 1 day (0.028 mg g^{-1}). The maximum crude fat content was obtained for seeds treated for duration of 3 days (52.4%) and the minimum was for duration of 2 days (42%). The results show that total protein content was the highest for decreased with decrease in hydropriming duration. No such trends was observed with respect to the carbohydrate and crude fat content for the seeds subjected to hydropriming.

The biochemical constituents of seeds plays an infinite role in enhancing the germination and seedling growth .The seed reserve material content is correlated with the germination percentages or speed of germination (Soriano *et al.*,2014). Biopriming results in biochemical changes including, enhanced production of hormones, proteins, phenols and flavonoids for better plant growth .Soluble protein range in biochemical seed is higher than the control (Dhanya, 2014). There was increase in protein and free amino acid content during different stages after priming with PGPR (Aishwath *et al.,* 2012; Warwate, 2017). Total soluble sugars and reduced sugar content in plant increased after bio-priming (Hafsa, 2014). Efficient mitochondrial development by augmenting energy metabolism by high ATP pool and increased ATP producing system occurs due to early imbibition process in primed seeds. (Chen *et al.,* 2013). Several mechanisms are reported to define the role of biopriming to enhance the nutritional value of the plant products by phosphate solubilisation, increased nitrogen fixation, increased production of plant growth – promoting compounds like phytohormones, production of antibiotics and decomposition of organic matter (Sinha *et al.,* 2014). Rhizosphere microbes plays an important role in enhanced uptake of Nitrogen, Phosphorus and Pottassium (Sharma *et al.,* 2015). Nitrogen, Phosphorus and Potassium are the major constituents of several enzymes, hormones, amino acids and genetic materials in plants which in turn has an important role in various physiological process in plants (Krouk *et al*., 2010). Yadav*et al.,* (2017) describes that seed chickpea seeds treated with Trichoderma sp. and *Pseudomonas fluorescens* shows an increased nutrient uptake of N, P, K, Na, Ca and organic matter and also results in increase in total phenolic content , total flavonoid content , carbohydrate and protein content of the seeds .There is also an increase in number of branches, grains per plant , 1000 grain weight , diameter of head ,grains per head , grain content and oil yield for seeds subjected to biopriming with Pseudomonas sp.(Sharif ,2012). IAA one of the prime auxin in plants products by *Pseudomonas fluorescens* , *Trichoderma viride* and PGPR 2 , regulates cell division ,enhances photosynthetic activities , and activated the translocation of carbohydrates , that enhances root initiation , flowering , fruit setting and ripening (MacDonald ,1997).

5.4. Effect of seed priming techniques in the seedling growth

With regard to the seedling attributes, for the seeds subjected to biopriming with *Pseudomonas fluorescens*, the maximum seedling growth was obtained at 50% for 1 day and minimum for 100 % for 3 days (for 30 DAT and 180 DAT) for the seeds stored for one day. For one week storage, the maximum value for seedling growth is obtained at 100% for 8 days in both growth periods and minimum for 50% for 6 days (30 DAT) and 75% for 3 days (180 DAT). The biomass accumulation was maximum on priming at 50 % for 1 day and minimum for 25% for 4 days during both growth periods. But for one week storage, the maximum value is obtained at 100 % for 6 days and minimum for 75% for 3 days. The vigour index was the highest for 75% for 1 day (1083.1) and lowest is at 25 % for 4 days (21.5) at 30 DAT and at 180 DAT, priming at 75% for 1 day

(1488.7) recorded the highest value and at 25% for 4 days (63.3) recorded the lowest for the seeds stored for one day. For the post priming storage of one week, highest VI was at 100% for 6 days (2184) and the lowest was at 100 % for 3 days (159.) At 180 DAT, seeds bioprimed at 100% for 6 days (3225) recorded the highest VI of and that at 100% for 3 days (364) recorded the lowest VI. From the study it can be seen that for one day storage, the maximum total seedling growth was obtained for higher duration and vice versa for the seeds stored for one week the trend is reversed for biomass production and vigour index of the seedlings. Kandolia and Vakharia (2013) had reported that the plant growth promoting effect of *P.flouorescens* is due to production of substances like salicylic acid, siderophore and IAA.

With respect to the seeds bioprimed with *Trichoderma viride* the maximum value of seedling growth was obtained at 25% concentration for 4 days (30 DAT and 180 DAT) and the minimum was obtained for 25 % for 3 days for both periods for the seeds stored for one day and for the seeds stored for one week the maximum growth was obtained at 100% for 3days and the lowest at 50% for 6 days. The biomass production was maximum at 100 % for 1 day and minimum for 50% for 1 day during both growth periods for the seeds stored for one day .For the post priming storage of one week the biomass production was the highest at 75% for 1 day and lowest at 75% for 4 days. The vigour index was the largest for priming at 100% for 1 day (1193.5) and the lowest was at 25% for 3 days (69.8) for 30 DAT and at 180 DAT the seedlings bioprimed at 100 % for 1 day (2052) and at 25% for 3 days (140) recorded the lowest VI for the seeds stored for one day. For one week storage the maximum value was at 100% for 3 days (2274.2) and the lowest was at 75 % for 2 days (89.4) at 30 DAT and at 180 DAT the highest VI is at 100% for 3 days (3332) and the seeds primed at 75% for 2 days (200) recorded the lowest VI. Results indicate that for post priming storage of the seeds for one day and one week the maximum seedling growth was obtained at same duration and concentration but minimum value is for lower duration in seeds stored for one day and vice versa for one week. For biomass production and vigour index, the maximum value was obtained for the seed stored at one day and one week the maximum value is obtained at the lower duration. Many microorganisms like Trichoderma spp. produces organic acids and phosphatase that solubilise the unavailable phosphate to its available form that can be easily absorbed by plants. Trichoderma sp also helps to increase the nitrogen use efficiency in plants (Rakshit *et al*., 2015a)

The capacity of *Trichoderma* spp. to produce growth hormones such as auxins and gibberelins were reported as the main factor that contributes to their ability to support root growth and increase water absorption from soil (Arora et al., 1992; Contreras-Cornejo et al., 2009; Martínez-Medina et al., 2011). Trichoderma induces IAA production and so it helps root growth and seedling quality in different plants (Morales *et al.,* 2004 and Graval *et al.,* 2006).

For the seeds bioprimed with PGPR II the maximum seedling growth was obtained at 75% for 4 days and the lowest was obtained at 50% for 6 days at 30 DAT and at 180 DAT maximum value was obtained at 100% for 6 days and the lowest was at 50% for 6 days for one day storage., For the seeds stored for one week the maximum value was obtained at 100% for 6 days and minimum at100 % for 3 days. With respect to the biomass production, the maximum value was obtained at 75% for 1 day and the minimum at 50% for 1 day for the seeds stored for one day and for one week storage the maximum value is obtained at 50% for 3 days and minimum at 50% for 1 day). The maximum vigour index was obtained at 75% for 1 day (593.8) and lowest at 100 % for 8 days (52) at 30 DAT and at 180 DAT, seedlings bioprimed at 75 for 1 days (859) recorded the highest VI and

those at 50% for 8 days (143) recorded the lowest VI. For the post priming storage of one week, the largest VI was at 50% for 3 days (2241.7) and the lowest was at 75% for1 day (31.5) at 30 DAT and 180 DAT, seedlings bioprimed at 50% for 3 days (3223) recorded the highest VI and at 75% for 1 day (75.3) recorded the lowest VI. The result showed that for the post priming storage of one day and one week the best seedling characteristics were obtained at almost same duration but at higher concentration for one day storage. On considering the biomass production the seeds stored for one day and one week, maximum is obtained at same highest duration. The vigour index of the seeds for both one day and one week storage obtained at lowest duration, the treatment with largest vigour index for one day shows minimum value when subjected to the post priming storage of one week. PGPR are known in various cropping systems to increase plant growth and seedling vigour (Lavakush *et al.,* 2014). Mechanisms of PGPR mediated plant growth promotion includes, bacterial synthesis of important plant hormones such as gibberellin, IAA, and increased uptake of phosphorus and other essential minerals

For the seeds that are subjected to hydropriming, the maximum seedling growth was obtained for the seeds hydroprimed for 8 days and minimum for 4 days (30 DAT) and maximum for 2 days and minimum at 4 days (180 DAT) for the seeds subjected to post priming storage of one day and at one week, the maximum value is obtained at a duration of 8 days and minimum value at 3 days. The biomass production was maximum the hydropriming 4 days and lowest was for 1 day at 30 DAT and at 180 DAT maximum biomass was obtained at the priming duration of 6 days and minimum at 1 day. For one week storage, the maximum biomass was obtained at the priming duration of 6 days and the minimum at of 2 days. The vigour index was the maximum 30 DAT was for 8days (877.2) and the lowest was for 1 day (34.9) and at 180 DAT, seeds hydroprimed for 8 days (1212.6) recorded the highest vigour index and for 4 days (83.7) recorded the lowest. For one week storage, the highest vigour index at 30 DAT was for 8 days (1016) and the lowest was for 4 days (177) and at 180 DAT, seeds hydroprimed for 8 days (1681) recorded the highest vigour index and the seeds hydroprimed for 4 days (313) recorded the lowest vigour index. From the results it is clear that for one day storage maximum seedling characteristics were obtained at higher duration and for the seed stored for one week lower duration. For biomass production, the minimum value is obtained at same lowest duration for one day and one week storage. For vigour index maximum is obtained for same highest duration for both the seeds stored for one day and one week. Plant growth promoting effect of hydropriming with enhanced seedling establishment, plant biomass, grain yield per unit area and yield attributes have been reported in some crops (Golezani *et al*., 2010).Trichoderma sp. enhances plant growth by increasing nutrient uptake (Rakshit *et al.,* 2013) along with the induction of secondary root development through auxins and indole production (Contreras-conrnejo *et al.,* 2009, 2014a, b). Hydropriming mainly improves germination as a result of the enhanced water uptake and more favourable water relations in primed seeds (Lechowska *et al*., 2019).

After hierarchical cluster analysis at 10% level, for the seeds subjected to post priming storage for one day the best performance with regards to the seedling growth attributes is obtained for the seeds bioprimed with *Trichoderma viride* 25% for 4 days. For one week storage the best falls in the seeds bioprimed with *Pseudomonas fluorescens* 100% for 8 days. This result is similar to a study made in Okra where the difference in the performance based on seed yield and seedling characteristics were for Trichoderma and Pseudomonas showed a higher performance in the next season for the same variety (Raj, 1990).

The results of the present study indicated the superiority of biopriming methods over the hydropriming treatments. Plant associated microorganisms fulfil important functions for plant growth and health (Gabriele Berg, 2009). The increase in vigour index and other growth parameters may be due to certain plant growth hormones and secondary metabolites produced by Pseudomonas and Trichoderma (Lynch and Hobbie, 1991). The bioinoculants used in the study as stated above stimulates the production of Indol Acetic Acid (IAA). IAA production plays a crucial role in plant growth promotion and the increased dry matter production is positively correlated with the production of IAA (Baker *et al.*, 1984). Increase in IAA content in the plant by biopriming enhanced number of roots , root hairs , root area , plant cell division , cell differentiation , xylem and root development , lateral and adventitious root formation , pigment formation and biosynthesis of various metabolites(Spaepen *et al.*,2011).

Podile and Kishore (2006) conclude several plant growth promoting (PGP) mechanisms of PGPR such as modification and increased branches in root hair, improvement in germination of seeds, enhanced and faster nodule performance, increase in leaf area per plant, release of certain phytohormones, augmented nutrients and water uptake by plants, increased biomass of the plants with more vigour growth and better carbohydrate accumulation which increases the growth of plant species. On the other hand, Glick (2003) categorizes the bacterial assisted plant growth in three different ways, including plant hormone production (Dobbelaere, Vanderleyden and Okon 2003), bacterial assisted better nutrient uptake by plants (Çakmakçi *et al*. 2006) and avoiding the diseases in plants through biological control (Saravanakumar *et al.*2008). Dey *et al*. (2004) suggest the need of exploring other mechanisms of plant growth promotion by PGPR apart from the list already studied. Listing all the explored and investigated mechanisms of PGPR, following can be included: (a) solubilization and mineralization of nutrients notably phosphorus (Richardson 2001; Banerjee and Yesmin 2002); (b) nitrogen fixation through symbiosis and asymbiosis (Kennedy, Choudhury and Kecskés 2004); (c) release of certain plant hormones such as gibberellic acid and cytokinins (Dey *et al.*2004), indole acetic acid (Patten and Glick 2002) and abscisic acid (Dobbelaere, Vanderleyden and Okon 2003); (d) production of 1-aminocyclopropane-1-carboxylate (ACC)-deaminase helping to lower ethylene level in roots this increasing length and vigor of roots (Li *et al.*2000; Penrose and Glick 2001); (e) antagonism toward plant pathogens by producing substances such as cyanides and antibiotics (Glick and Pasternak 2003); (f) increasing the availability of nutrients specifically of iron through chelating by producing siderophores (Glick and Pasternak 2003); (g) tolerance against several abiotic stresses such as oxidative (Stajner *et al*. 1995, 1997) and drought stress (Alvarez, Sueldo and Barassi, 1996); (h) water soluble vitamin production including biotin, niacin, thiamine and riboflavin (Revillas *et al.*2000); (i) detoxification of heavy metals (Ma *et al.*2011); (j) tolerance of salinity (Tank and Saraf 2010); and (k) biological control of pests and insects (Russo *et al.*2008).

SUMMARY

The present study entitled the impact of seed biopriming on the germination and seedling growth of *Sandal* (*Santalum album* L.) was carried out at the College of Forestry, Vellanikkara, Thrissur, Kerala. The sandal seeds were collected from the Nachivayal Reserve Forest of Marayur Sandal Division. The study analysed the effect of concentration and duration of three biopriming agents viz. *Pseudomonas fluorescens*, *Trichoderma viride* and Plant Growth Promoting Rhizobacteria (PGPR II) and hydropriming for different duration on seed germination and subsequent seedling growth in sandal. Biopriming was at four different concentrations of the bioinoculants (25, 50, 75 and 100%) for 6 (1, 2,3,4,6 and 8 days) and hydropriming was for the same durations. The primed seeds were stored for one day and one week after the completion of priming processes and the germination and seedling growth were observed. After germination the seedlings were transplanted to the nursery for to estimate the impact of priming on seedling growth attributes. The salient findings of the study are as follows:

1) On biopriming with *P. fluorescens,* the maximum germination was obtained for the seeds treated at 25% concentration for 3 days (34.61%) and the lowest was obtained for 50% for 2 days (0%) for the seeds stored for one day. The Mean Daily Germination, Plant Value and Germination Value were highest on biopriming at 25% for 4 days (4.00, 3.06 and 12.24, respectively) and the minimum 75% for one day (0.04, 0.09 and 0.0036 respectively). For one week stored seeds, the highest germination was obtained for the seeds that were subjected to biopriming at 100% for 6 days (81.26%) and the lowest was obtained for the seeds subjected to biopriming at 25 % for 3 days (8%). The MDG, PV and GV were highest for biopriming for 50% for 6 days (4.29, 4.74and 23.16, respectively) and the minimum for biopriming for biopriming for 50 % for 1day (0.74, 0.82, and 0.61, respectively).
2) For the seeds subjected to biopriming with *Trichoderma viride,* the highest germination was obtained for the seeds treated at 100 % for 1 day (73.3%) and the lowest value was obtained for biopriming at 25% for 8 days (2.61%) for the seeds stored for one day. The MDG, PV and GV were highest in biopriming at 25% for 4 days (4.91, 3.72, and 18.28, respectively) and the lowest was at 50 % for 2 days. (0.4, 0.27 and 0.11, respectively). For the seeds stored for one week the maximum germination was obtained at 100% concentration for 3 days (82.7225%) and the lowest was on biopriming at 100 % for 6 days (1.2201%).The MDG, PV and GV were highest for biopriming at 50% for 3 days (5.736, 6.411 and 36.78, respectively) and obtained minimum values for 100% for 8 days (0.371, 0.49 and 0.18221, respectively).
3) For seeds bioprimed with PGPR II, the maximum germination was obtained for the seeds that are treated at 75 % concentration for a duration of 6 days (29.36%) and lowest value was obtained in biopriming at 50% for 3 days (1.22%). The MDG, PV

and GV was highest for biopriming at 25% for 2 days (4.55, 3.41 and 15.56,respectively) and minimum for 50% for 1 day (1, 0.25 and 0.25, respectively).For the seeds that are stored for one week the maximum germination was obtained at 50% for 3 days (76.6%) and the lowest was obtained at 100% for 3 days and for 25 % for 1 day (0%).The MDG, PV and GV were highest for biopriming for 25% for 3 day (6.76, 6.57 and 44.45 respectively) and the minimum for100% for 3 days and 25% for 1 day.

4) In context of the hydropriming , the maximum germination was obtained for the duration 2 days (30.13%) and the lowest was obtained for hydropriming for 1 day (6.39%) on storing for one day .The MDG, PV and GV were highest in 6 day soaking (3.11,2 and 6.22, respectively) and the lowest was for 4 day duration (2,0.52 and 1.04, respectively). For one week stored seeds, the maximum germination percentage was obtained at 8 days (56%) and the lowest was obtained for the seeds subjected to hydropriming for 4 days (10.62%). The MDG, PV and GV were highest for 6 days (3.38, 2.84, and 9.61, respectively) and the minimum for hydropriming for 8 days. (0.78, 0.878 and 0.6871 respectively).
5) Changes in biochemical composition of seeds after priming were also observed. For seeds bioprimed with *Pseudomonas fluorescens*, the highest total carbohydrate was obtained for the seeds bioprimed for 100% for 3 days (0.3337 mg g^{-1}) and the lowest was for 50% for 6 days (0.0879 mg g^{-1}). The maximum total protein content falls for the seeds bioprimed at 25% for 6 days (0.062 mg g^{-1}) and the minimum for that at 50% for 1 day (0.016 mg g^{-1}). On considering total crude fat content the maximum was obtained for seeds bioprimed for 100% for 3 days (73.2%) and the minimum for 100% for 2 days (44.6%).
6) For seeds bioprimed with *Trichoderma viride*, the maximum carbohydrate was obtained for seeds bioprimed for 25% for 3 days (0.722 mg g^{-1}) and the minimum for 75% for 2 days (0.110 mg g^{-1}). The total protein content was the maximum value on seeds bioprimed at 100% for 1 day (0.059 mg g^{-1}) and the lowest for 25% for 1 day (0.020 mg g^{-1}). The total crude fat content was the maximum on seeds bioprimed at 100% for 6 days (76.6%) and the minimum for 75% for 1 day (34%).
7) For the seeds bioprimed with PGPR II, the maximum carbohydrate was obtained for treatment at 100% for 1 day (0.370 mg g^{-1}) and the lowest was at75% for 4 days (0.127 mg g^{-1}). The total protein content was for priming at 25% for 4 days (0.077

mg g^{-1}) and the lowest was at 75% for 3 days (0.03 mg g^{-1}).Estimation of crude fat indicated that the maximum value was recorded for seed bioprimed at25% for 2 days (74%) and the lowest was for 75% for 6 days (44.6%).

8) During hydropriming, the maximum carbohydrate was obtained on soaking duration of 6 days (0.394 mg g^{-1}) and lowest was for 4 days (0.168 mg g^{-1}). The highest protein content was for soaking of 8 days (0.042 mg g^{-1}) and lowest was for the duration 1 day (0.028 mg g^{-1}). The maximum value for crude fat content was obtained for seeds hydroprimed for 3 days (52.4%) and minimum was for duration of 2 days (42%).
9) For the seeds treated with *Pseudomonas fluorescens* the maximum value of EC was obtained for seeds treated at 75% for 4 days (1.159dS cm^{-1}) and the lowest for 25% for 6 days (0.325dS cm^{-1}). For seeds bioprimed with *Trichoderma viride*, the highest value was obtained for seeds bioprimed for 75% for 6 days (1.320 dS cm^{-1}) and the lowest was for 75% for 1 day (0.217 dS cm^{-1}). On the context of biopriming with PGPR II the maximum value of electrical conductivity is obtained for 25% for 2 days (0.962 dS cm^{-1}) and minimum for 100% for 1 day (0.247 dS cm^{-1}). The value of electrical conductivity of seed leachates falls highest value for the seeds treated for the duration of 2 days (1.450 dS cm^{-1}) and the minimum was for 6 days (0.153 dS cm^{-1}).
10) On considering the seedling attributes like seedling height, collar diameter, number of leaves and leaf area, for the seedling subjected to biopriming with *Pseudomonas fluorescens*, the maximum value for seedling growth is obtained at 50% for 1 day and the minimum for 100 % for 3 days (for 30 and 180 DAT) for the seeds stored for one day. For one week storage, the maximum value for seedling growth was obtained at 100% for 8 days (for 30 and 180 DAT) and the minimum for biopriming at 50% for 6 days (30 DAT) and at 75% for 3 days (180 DAT). For biomass production the maximum value was obtained at 50 % for 1 day and the minimum for 25% for 4 days (30 and 180 DAT respectively). For one week storage, the maximum value was obtained at 50 % for 1 day and the minimum for 25% for 4 days (30 and 180 DAT). With respect to the vigour index, the highest value is for 75% for 1 day (1083.1) and the lowest is at 25 % for 4 days (21.5) and at 180 DAT, for 75% for 1 day (1488.7) recorded the highest value and at 25% for 4 days (63.3) recorded the lowest for the seeds stored for one day storage. For one week storage highest VI was at 100% for 6

days (2184) and the lowest at 100 % for 3 days (159). At 180 DAT, seeds bioprimed at 100% for 6 days (2184) recorded the highest VI and at 100% for 3 days (364) recorded the lowest.

11) With respect to the seeds bioprimed with *Trichoderma viride* the maximum value of seedling growth was obtained for 25% for 4 days (30 and 180 DAT respectively) and the minimum was obtained for 25 % for 3 days (30 and 180 DAT respectively) for the seeds stored for one day and for the seeds stored for one week the maximum seedling growth was obtained at 25% for 4 days and the lowest at 100% for 6 days (30 and 180 DAT, respectively). Considering the biomass production, the maximum value was obtained at 100 % for 1 day and 50% for 1 day (30 and 180 DAT respectively) for the seeds stored for one day. For one week storage, the biomass production has its maximum value at 25% for 4 days and the lowest at 75% for 4 days (30 and 180 DAT respectively). Comparison of vigour index indicated that, the highest is at 100% for 1 day (1193.5) and the lowest was at 25% for 3 days (69.8) for 30 and 180 DAT respectively and the seedlings bioprimed at 100 % for 1 day recorded the highest (2052) and at 25% for 3 days (140) recorded the lowest VI for the seeds stored for one day. For one week storage, the maximum value was on priming at 100% for 3 days (2274.2) and the lowest was at 25% for 3 days (69.8) at 30 DAT and at 180 DAT the highest VI was at 100 % for 3 days (3332) and the seeds at 75% for 2 days (200) recorded the lowest VI.

12) For the seeds bioprimed with PGPR II, the maximum seedling growth was obtained on biopriming at 75% for 4 days and the lowest was obtained at 50% for 6 days at 30 and 180 DAT maximum value was obtained at 100% for 6 days and lowest at 50% for 6 days for one day storage. For the seeds stored for one week the maximum value was obtained at 100% for 3 days and 75% for 2 days (30 and180 DAT, respectively). With respect to the biomass production, the maximum value was obtained for 75% for 1 day and minimum at 50% for 1 day (30 and 180 DAT, respectively) for the seeds stored for one day and for one week storage the maximum value was obtained at 50% for 8 days and was minimum at 100% for 8 days (30 and 180 DAT respectively). Concerning the vigour index, the maximum value was obtained for priming at 75% for 1 day (593.8) and the lowest was at 100 % for 8 days (52) at 30 and at 180 DAT, respectively, seedlings bioprimed at 75 % for 1 days (859) recorded the highest VI and those at 50% for 8 days (143) recorded the lowest VI. For the

seeds stored for one week, the largest VI was at 50% for 3 days (2241.7) and the lowest was at 75 % for 1 day (52) at 30 DAT and 180 DAT, seedlings bioprimed at 50% for 3 days (3223) recorded the highest VI and at 75% for 1 day (75.3) recorded the lowest VI.

13) For the seeds that are subjected to hydropriming, the maximum value for seedling growth was obtained for the duration of 8 days and minimum fort 4 days (30 DAT) and the maximum is at the duration 8 days and minimum at 1 day (180 DAT) for the seeds primed and stored for one day. For biomass production the maximum value was obtained for the seeds subjected to the 4 days hydropriming and the lowest was for 1 day at 30 and at 180 DAT maximum was obtained at the priming duration 6 days and minimum at 1 day. For one week storage, the maximum was obtained at the priming duration 4 days and the minimum for 8 days. With respect to the vigour index the maximum value obtained at 30 DAT was for 8 days (877.2) and the lowest was for 1 day (34.9) and at 180 DAT, seeds hydroprimed for 8 days (1212.6) recorded the highest vigour index and for 4 days (83.7) recorded the lowest. For one week storage, the largest vigour index at 30 DAT was for 8 days (1016) and the lowest was for 4 days (177) and At 180 DAT, seeds hydroprimed for 8 days (1681) recorded the highest vigour index and the seeds hydroprimed for 4 days (313) recorded the lowest vigour index.

14) Among the three bioinoculants , the germination percentage obtained was maximum for the seeds treated with *Trichoderma viride* for 100 % for 1 day (73.3%) followed by *Pseudomonas fluorescens* for 25% for 1 day, *P. fluorescens* for 75% for 1 day, *T viride for* 25% for 1 day and *Trichoderma viride for* 75% for 1 day(35.966%) and the minimum germination percentage was obtained for the seeds bio primed with *P. fluorescens* for 50% for 2 days (0 %), for the bioprimed seed stored for one day.

15) For one week storage, the maximum germination percentage was obtained for the seeds bioprimed with *T. viride* for 100 % for 3 days (82.72%) followed by *P. fluorescens* for 100% for 6 days (81.27%) and the minimum germination percentage was obtained for seeds bioprimed with PGPR II for 25% for 1 day and PGPR II for 100% for 3 days (0%).

16) After cluster analysis of the seedling attributes the best falls with the seeds bioprimed with *Trichoderma viride* at 25% for 4 days (30 and 180 DAT) for the seeds subjected to post priming storage for one day. For the seeds subjected to post priming storage

for one week, the best falls with the seeds bioprimed with *Pseudomonas fluorescens* at 100 % for 8 days (30 and 180DAT).

Overall it can be concluded that the seeds subjected to biopriming for lower concentration and duration of the bioinoculant has also given considerable increase in the germination and growth attributes. Since biopriming is the most cheapest method of priming after hydropriming and also is an environment friendly technique it can be suggested as an emerging technique for improving the germination percentage and seedling attributes of *Santhalam album.* Furthermore, changes in the biochemical attributes given by bioinoculant on germination and seedling attributes with respect to the differences in the storage of the primed seeds must be studied.

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Biopriming techniques for better germination and seedling growth of sandal (*Santalum album* L.)

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ABSTRACT OF THE THESIS

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Abstract

Seed priming is the process of controlled hydration of seeds to a level that permits pre-germinative metabolic activity to proceed, but prevents actual emergence of the radicle. Seed priming with living bacterial inoculums is known as biopriming, which involves the application of plant growth promoting rhizobacteria (PGPR), resulting in enhanced germination, plant growth and disease résistance. *Santalum album*, L is a semi-root parasitic tree distributed in South India and is one of the most valuable and world renounced timber species. The poor germination rate combined with the long germination period is a major limitation in the regeneration of sandal. The present study was formulated to evaluate the

effect of seed biopriming procedures on the germination and seedling performance of *Santalum album*. The biopriming agent's viz. *Pseudomonas fluorescens, Trichoderma viride*, PGPR II at concentrations 25, 50, 75 and 100% and durations 1, 2,3,4,6 and 8 days and hydropriming for the same duration constituted the treatments of the study. The primed seeds were sown after the post priming storage for one day and one week. The results indicated that, for the post priming storage of one day, biopriming with *T. viride* at 100 % for 1 day (73.3%) followed by *T viride* at 75% for 1 day (35.96%) recorded the highest germination and the lowest was on biopriming with *P. fluorescens* at 50% for 2 days (0 %). Whereas, for post priming storage of one week, the highest germination was obtained on biopriming with *T. viride* at 100% for 3 days (82.72%), followed by *P. fluorescens* at 100% for 6 days (81.27%) and the lowest germination was obtained for the seeds bioprimed with PGPR II at 25% for 1 day and PGPR II at 100% for 3 days (0%). The shortest imbibition period was observed for the seeds bioprimed with *P. fluorescens* at 100% for 8 days (13 days) for one day storage and for the seed subjected to post priming storage of one week, for majority of the treatments, the imbibition period was reduced to 15 days.

The electrical conductivity of the seed leachates, was the maximum for the seeds hydroprimed for 3 days (1.469 $dScm^{-1)}$ and the lowest was in hydropriming for 6 days (0.172$dScm^{-1}$) and for the seeds subjected to biopriming the range of electrical conductivity varies from 0.266 dS cm^{-1} (PGPR II at 100% for 1 day) to 1.32 $dScm^{-1}$(*T. viride* at 75% for 6 days). Biochemical analysis of the seeds after priming indicated that the total carbohydrate was maximum on biopriming with *T. viride* at 25% for 3 days (0.772 mg g^{-1}) and the lowest value was on biopriming with *P. Fluorescens* at 50% for 6 days (0.088 mg g-1). The total protein was maximum for the seeds treated with PGPR II at 25% for 4 days (0.077 mg g-1) and the lowest was for those treated with *T. viride* at 50% for 2 days (0.016 mg g-1).Crude fat content of the primed seeds was maximum for the seeds treated with *P. fluorescens* at 100% for 3 days (73.2%) and the minimum for those treated with *T. viride* at 75% for 1 day (34%). Seedling growth and biomass production were recorded at 30 and 180 days after transplanting. In the context of seedling attributes, the maximum seedling height is observed for the seeds bioprimed with PGPR II at 100% for 2 days (27.2 cm), the largest collar diameter was for *T viride* at 25% for 4 days (4.08mm) and the maximum number of leaves is obtained for *T viride* at 75% for 8 days (26.7) for the seeds subjected to post priming storage of one day. For one week storage, the largest value for seedling height is obtained for seeds bioprimed with *P. fluorescens at* 100% for 8 days (28.10 cm), the collar diameter was obtained maximum for biopriming with *P. fluorescens at* 100% for 8 days (5.63 mm) and the largest number of leaves is obtained for *T. viride* at 100% for 1 day (23.7). Hierarchical cluster analysis indicated that the best seedling performance was on biopriming with T. *viride* at 25% for 4 days for one day storage and *P. fluorescens* at 100% for 8 days, for the seeds subjected to post priming storage of one week at 30 and 180 days after transplanting. The present investigation confirms the superiority of biopriming treatments in improving the germination and seedling

performance of the sandal and biopriming being an eco-friendly treatment that can be recommended for the quality planting stock production of sandal.