RESPONSE OF HIGH YIELDING VARIETIES OF PEARL MILLET [*Pennisetum glaucum* (L.) R. Br.] TO MAJOR NUTRIENTS

By

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2021

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

(AGRONOMY)

Faculty of Agriculture

Kerala Agricultural University

Department of Agronomy

COLLEGE OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

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2021

DECLARATION

I, **Murshida S. (2019-11-130)** hereby declare that this thesis entitled **"Response of high yielding varieties of pearl millet [*Pennisetum glaucum* (L.) R. Br.] to major nutrients"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

05/11/2021

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CERTIFICATE

Certified that this thesis entitled **"Response of high yielding varieties of pearl millet [*Pennisetum glaucum* (L.) R. Br.] to major nutrients"** is a bonafide record of research work done independently by **Ms. Murshida S. (2019-11-130)** 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.

5.11.2021

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We, the undersigned members of the advisory committee of **Ms. Murshida S. (2019-11-130)**, a candidate for the degree of **Master of Science in Agriculture** with major field in **Agronomy**, agree that this thesis entitled **"Response of high yielding varieties of pearl millet [*Pennisetum glaucum* (L.) R. Br.] to major nutrients"** may be submitted by **Ms. Murshida S.** in partial fulfillment of the requirement for the degree.

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ACKNOWLEDGEMENT

First and foremost, ***Alhamdulillah****. I owe my heartfelt gratitude towards the* ***Almighty Allah*** *for all the boundless blessings showered upon me to complete my research work successfully ahead of all the odds I faced.*

This this is the ending of my M.Sc. in Agronomy with the support and encouragement of many people including my well-wishers, my respectable teachers, my beloved parents, my friends and relatives.

My words cannot express the deep sense of immeasurable gratitude, extreme indebtedness of whole hearted gratitude to my major advisor ***Dr. P. Prameela****, Professor and Head, Department of Agronomy, chairperson of my advisory committee. With great respect and devotion, I wish to place my heartfelt thanks to her for the inspiring guidance, untiring interest, unstinted co-operation, esteemed advice, constructive criticism, practical suggestions, constant patience and immense help rendered by her during the investigation and preparation of the thesis. I am genuinely indebted to her for the constant encouragement, gracious persuasion, affectionate advice and unfailing support with friendly approach rendered throughout the academic programme and will be remembered forever. I consider myself being fortunate in having the privilege of being guided by my dearest ma'am.*

I would like to express my extreme indebtedness and obligation to ***Dr. Meera V. Menon****, Professor, Cashew Research Station, Kerala Agricultural University and member of my Advisory Committee for her expert advice, valuable suggestions, critical evaluation and support accorded during my field and thesis works.*

I feel highly privileged to express the deep sense of gratitude to my advisory committee member, ***Dr. Savitha Antony****, Assistant Professor, Department of Agronomy, College of Agriculture for her propitious guidance, keen interest, helpful advices and encouragement during the course of study.*

I am ever grateful to ***Dr. Divya Vijayan V,*** *Assistant Professor (Soil Science), STCR (Soil Test Crop Response) and member of my Advisory Committee for her encouragement, valuable help, timely suggestions and affectionate advice rendered during the course of study.*

It is with my heartfelt feelings, I am especially indebted with my deep sense of gratitude and sincere thanks to my beloved teachers of Agronomy Department ***Dr. Sindhu P. V, Dr. S. Anitha, Dr. Syama S. Menon,*** **Smt. Raji S. Prasad, Smt. Jayashree and Smt. Anjana S. R.** *for their encouragement, moral support, valuable help and advices which have provided good and smooth basis for my studies. I am also extremely grateful to our respectable teachers* ***Dr. C. George Thomas*** *and* ***Dr. P. S. John*** *for their valuable informations accorded during my studies.*

My heartfelt thanks to ***Dr. Jayashree Shankar****, Professor and former Head of Soil Science and Agricultural Chemistry, for the timely help during the research programme. I am thankful to* ***Mr. Aravind K. S.*** *and* ***Mrs. Rajitha*** *of Students' Computer Club, College of Agriculture, Vellanikkara for rendering necessary help whenever needed. I thankfully remember the services rendered by all the staff members of Student's Computer Club, Library, Office of COH and Central Library, KAU.*

I wish to express my sincere gratitude to ***Mrs. Sreela,*** *and* ***Mrs. Shyamala****,* ***Mrs. Midhuna*** *for the sincere help, timely suggestions, encouragement and mental support during the research works. I owe my deepest gratitude to* ***Ms. Athira*** *and* ***Mr. Sijith*** *(Farm Managers, Dept of Agronomy), and I am deeply indebted to the labourers of Dept. of Agronomy for the timely help and cooperation during my field experiments.*

I duly acknowledge the encouragement and timely persuasions and precious suggestions by my dear classmates, ***Oormila T. P, Shakkira K. K, Aswani S, Saveri Gopakumar, Dayana Samson, Fasna*** *and* ***Ayisha Jezla****. I also express my thankfulness to all my dear seniors,* ***Ms. Jeena Mary, Ms. Teresa Alex, Ms. Divya, Ms. Daly George, Ms. Durga, Mr. T. V. Reddy, Ms. Vidhu Priyadarshini*** *and* ***Mr. Ajmal Fayique*** *and juniors,* ***Basil, Ribin, Junaidath*** *and* ***Dibina*** *of department of Agronomy for their constant support throughout my research period. Special word of thanks to* ***Ms. Jeen Shaji, Ms. Anjali Vijay, and Dr. Shobha Rani*** *for their timely and sincere help.*

I am extremely delightful to acknowledge my profound sense of gratitude to our ***Agronomy family*** *of College of Agriculture, Vellanikkara for their affectionate advice, valuable help, constant support, cooperation as well as giving a tenderhearted and loving family atmosphere throughout the course of study.*

I have infinite pleasure to express my love towards my best friends ***Sikha, Nitha, Veevee, Anjali, Sreelu, Sreesha, Snehap, Swathi, Rahul, Deepthi, Dhanya, Kavya*** *and for all batchmates of* ***Gagnants*** *as well as* ***Dinkan et al.*** *for their affection, moral support, innumerable help and encouragement. I duly express my heartful thanks* ***Mohanan chettan*** *and* ***Priya aunty*** *in providing a homely stay with their love and fun filled moments during this covid pandemic situations to conduct my field studies smoothly.*

I am in dearth of words to express my love towards to my beloved parents ***Mr. Alavi Srambikkal*** *and* ***Mrs. Ramla A. M****, my best friend cum life partner* ***Mr. Ashique E****, parents in law* ***Mr. Abdul Latheef E****. and* ***Mrs. Hafsath****, Sisters* ***Muhsina and Munsila,*** *brother* ***Muneef*** *and sisters in law* ***Shamna*** *and* ***Shabna*** *and to my all* ***family members*** *for their prayers, blessings, support, motivation, inspiration and sacrifice without which this endeavour would never have become a reality. I also express my love to my* ***Lechu and Lennu*** *who made me smile even in tough times.*

It would be impossible to list out all those who have helped me in one way or another, for the completion of my work. I once again express my heartfelt thanks to all those who helped me in completing my work on time directly or indirectly. Thanking the Almighty.

Thanking all,

Murshida S.

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1. Introduction

1. INTRODUCTION

Pearl millet or bajra [*Pennisetum glaucum* (L.) R. Br.] is a staple food for people living in the arid and semi-arid tropics of the world, where half of the global millet production is concentrated. Bajra is the sixth most significant field crop in world after rice, wheat, maize, barley and sorghum and is the fourth most widely cultivated food grain crop in India after rice, wheat and maize. It is usually designated as "poor man's food" and is also known by the common names cat tail millet and candle millet.

In India, pearl millet occupies 7.52 million ha area with an average production of 10.28 million tonnes and productivity of 1368 kg/ha (GOI, 2021). India is the world's leading producer and major states are Rajasthan, Uttar Pradesh, Haryana, Gujarat, Maharashtra, Karnataka and Tamil Nadu which account for more than 90% of area under this crop. Government of India observed the year 2018 as the "Year of Millets" and UN General Assembly has recently adopted a resolution for declaring the year 2023 as "International Year of Millets" to encourage the millet cultivation and to explore the rich nutritional properties of these climate resilient crops.

Pearl millet is nutritionally superior with non-acid forming, non-glutinous grains having several nutraceutical properties. It is getting popularity among health conscious people all over the world, as a good source of carbohydrate, protein, dietary fibre, anti-oxidants, vitamins like riboflavin and thiamine, minerals like potassium, phosphorus, magnesium, iron, zinc, copper and manganese. It is also a dual purpose crop, as the grains are used for human consumption and straw is a good fodder.

Pearl millet can be recommended as a contingent crop also. The crop's fast growth rate and short duration gives a remarkable ability to perform under most adverse climatic conditions and hence it is also known as "climate smart crop". It grows well in shallow and infertile soils with poor water holding capacity, where other food grain crops fail. It is tolerant to saline and acidic soils, but does not perform well under water logged conditions.

Nutrient management is critical to enhance the crop productivity and reports show that pearl millet responds positively to balanced nutrient application. According to Jakhar *et al*. (2006), application of fertilizers along with farm yard manure enhanced the crop growth and development as well as increased the grain yield of bajra. The addition of primary nutrients is very essential for achieving the potential yield of pearl millet. However, the fertilizer requirement varies with several factors such as nutrient status of soil, climatic conditions, varieties, soil moisture availability *etc*. Higher crop productivity can be achieved by cultivating high yielding varieties along with optimum rates of fertilizer application.

A number of high yielding varieties of pearl millet have been released from various State Agricultural Universities and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad. Some of the major varieties/ hybrids under cultivation in India are ICMV 155, Co 10, Phule Aadishakti, Kaveri Super Boss, Dhanashakthi, Co (Cu) 9, ABV 04, Co 9, Pusa Composite 612, ICMV 221, Pusa Safed, Samrudhi, Anantas, Phule Mahashakti *etc*. Of this, Dhanashakthi is the world's first high iron bio-fortified variety (81 ppm Fe) released from ICRISAT in 2014 and ABV 04 is an open pollinated short duration variety with higher amount of iron and zinc released from Acharya NG Ranga Agricultural University, Telegana in 2019.

Though, studies on fertilizer requirements of pearl millet have been conducted at different parts of the country, in Kerala, such studies have not been undertaken. As many high yielding varieties of bajra are now available for cultivation, there is a need to standardise the fertilizer requirement of these varieties. Besides, the performance of pearl millet varieties has to be assessed in our climatic condition. Hence, the present research programme was formulated with the objective of assessing the performance of selected prominent high yielding varieties of pearl millet and their response to major nutrients.

2. Review of Literature

2. REVIEW OF LITERATURE

Cultivation of millets is gaining importance presently in the context of rise in global temperature and aberrant weather conditions, as these are climate resilient crops. Though pearl millet is a crop that can be grown in Kerala, there are only very limited studies conducted. A number of high yielding varieties of pearl millet released from various agricultural universities are available for cultivation. However, there is limited information about the suitability of these varieties to our climatic conditions and requirements of primary nutrients by pearl millet. Higher crop productivity can be achieved by cultivating high yielding varieties along with optimum rates of fertilizer application.

2.1 Nutrient management in pearl millet

As the nutrient status varies with soil types, it is important to promote the soil test based nutrient management for the enhancement of fertilizer use efficiency by the judicious use of resources and proper nutrient supplementation. Although the nutrient requirement of local varieties of bajra can be easily met by the application of organic manures @ 10-15 t/ha, the nutrient demand of high yielding varieties can be met only by the supplementation of inorganic fertilizers (Singh *et al*., 1977).

Brar (1980) studied the influence of fertilizer dose on different growth parameters of bajra. According to Nanwal (1991), there was an enhancement in the grain weight per earhead and 1000 grain weight with the increase in soil fertility level. Kumar *et al*. (1995) reported that there was significant improvement in plant height, tillers per square meter and dry matter accumulation of pearl millet with increase in fertility level of the soil. According to Jakhar *et al*. (2006), application of fertilizers along with farm yard manure enhanced the crop growth and development as well as increased the grain yield of bajra.

The best method to boost the crop productivity of bajra is by balanced fertilizer application through foliar feeding (Rana *et al*., 2012). According to Kumar *et al*. (2014), a significant correlation was recorded in all the biometric and yield

parameters under rainfed conditions by the application of NPK fertilizers at the right dose and time. In arid areas, because of uncertainty of rain, farmers use very less inorganic fertilizers which is the one of the major factor responsible for less yield (Bamboriya *et al*., 2017).

2.2 Effect of nitrogen on growth and yield of pearl millet

The addition of nitrogenous fertilizers is very essential for obtaining potential yield of pearl millet as most of the Indian soils are deficient in nitrogen. Dahiya and Singh (1977), Upadhyaya *et al*. (1977) and Khan *et al*. (1979) reported that the optimum dose of nitrogen for hybrid pearl millet is in the range of 120 and 160 kg/ha. Joshi and Kalla (1986) reported that the nitrogen requirement for hybrids was greater compared to local varieties, since the hybrids had better production potential.

Kaushik and Gautam (1987) reported that there was a significant increase in the number of tillers per plant with increasing the nitrogen levels. Bheemaiah *et al*. (1988), evaluated the performance of pearl millet varieties on sandy loam soils of Hyderabad and observed the enhancement of grain yield with increasing levels of nitrogen. The N uptake of hybrids and high yielding varieties of bajra were higher than local types (Wani *et al*., 1990).

The availability of adequate quantity of nitrogen till grain filling stage could ensure increased vegetative growth of bajra (Yadav *et al*., 1991). According to Tomar *et al*. (1995), grain and herbage yield of pearl millet improved by increasing the amount of nitrogen fertilizer up to 90 kg/ha. In black soils of Dharward, application of nitrogen fertilizer at 120 kg/ha over 80 kg/ha considerably improved performance of bajra in terms of plant height, tillers per plant and number of green leaves (Babu *et al*.,1995).

The addition of nitrogenous fertilizers to pearl millet enhanced crop growth and grain yield since nitrogen was one of the key nutrients in plant nutrition (Gascho *et al*., 1995). In an experiment conducted by Raghuwanshi *et al*. (1997), it was found that the application of 50 kg/ha nitrogen improved the plant height and test weight

of grains in pearl millet. The dry matter production and number of tillers per plant was enhanced by the application of increasing rates of nitrogen (Jangir *et al*., 1999). According to Yadav (1998), the height and number of tillers per plant of pearl millet increased with N fertilizer application at the rate of 80 kg/ha under rainfed conditions.

Khateek *et al*. (1999) observed better dry matter accumulation in bajra and height of plants by nitrogen application at increasing levels up to 45 kg/ha. The basal application of nitrogen at 20 kg/ha was reported as effective for obtaining higher grain yield of pearl millet irrespective of seasonal variations in rainfall (Jangir *et al*., 1999). Mesquite and Pinto (2000) registered positive correlation of maximum dry matter production with the application of 120 kg/ha of nitrogen in pearl millet.

Different levels of nitrogen application along with FYM positively influenced the yield parameters of bajra with a maximum grain yield of 1103 kg/ha from the application of N at 40 kg/ha and FYM at 5 t/ha, followed by N at 20 kg/ha and FYM at 5 t/ha (Kavimani *et al*., 2001). According to Munirathnam and Gautam (2002), split application of nitrogen showed an advantage over the basal application and the dose of 60 kg N/ha resulted in better yield.

There was significant increase in number of tillers per plant and plant height of pearl millet by the application of nitrogen at 60 and 90 kg/ha over 30 kg/ha (Chaudhari *et al*., 2002). According to Tiwana *et al*. (2003), higher number of tillers, plant height, leaf – stem ratio and Leaf Area Index (LAI) of pearl millet resulted by the application of 75 kg/ha of N. Besides, according to Ayub *et al*. (2007), application of 100 kg/ha of nitrogen to pearl millet improved the stover yield than doses of 50 and 150 kg/ha of N.

Singh *et al*. (2010) found that the application of N at the rate of 120 and 60 kg/ha resulted in the maximum growth of pearl millet hybrid 'HHB-67' under irrigated and rainfed conditions respectively in New Delhi. Jadhav *et al*. (2011) also reported considerable response of pearl millet to added nitrogen fertilizers. Since nitrogen promotes the vegetative growth of plant, higher rates of application of nitrogen also significantly improved the plant height (Reddy *et al*., 2012).

The response of different hybrids of pearl millet to different levels of nitrogen were studied by Kumari *et al*. (2017) who recorded maximum plant height (175.30 cm), number of tillers per plant (3.67), crop growth rate (1.53 g/m^2/day), relative growth rate (0.052 g/g/day), length of earhead (27.52 cm), number of grains per earhead (2406), test weight of grains (10.29 g), grain yield (3.72 t/ha), straw yield (6.98 t/ha) and harvest index (0.40) by the supplementation of NPK @ 100: 45: 45 kg/ha.

The application of 120 kg N/ha in three splits of one third of N as basal, one third at tillering and remaining one third at booting stage of pearl millet along with the recommended dose of phosphorus at 40 kg/ha registered the highest growth and yield performance with better grain quality on medium black soils of Maharashtra (Kadam *et al*., 2019).

2.3 Effect of phosphorus on growth and yield of pearl millet

Phosphorus is the second most important nutrient after nitrogen for the proper plant growth, development and crop productivity. The highest grain yield and herbage yield of pearl millet resulted from the application of super phosphate at 67.2 kg/ha along with 12.55 tonnes of FYM over the application of super phosphate 67.2 kg/ha alone (Indraraja and Sreeramulu, 1963).

Hybrids of pearl millet performed better and gave more grain yield of 100-150 kg/ha than local varieties by the application of phosphatic fertilizers alone to the crop (Dayanand and Bapat, 1976). According to Brar *et al*. (1980), there was a significantly different response to the application of phosphorus at 30 kg/ha to pearl millet. Lal (1980) found that application of phosphorus at 60 kg/ha to pearl millet significantly increased the grain and fodder yield.

Pareek and Shaktawat (1988) observed that there was a linear relationship between the levels of phosphorus from 0 to 50 kg/ha in earhead length, number of effective tillers per plant, grains per earhead and test weight of grains. Yadav (1990) concluded that the increasing level of phosphorus from 25-50 kg/ha in loamy sand soils of Jobner, Rajasthan greatly improved the performance of bajra over control by

enhancing the number of effective tillers per plant, test weight, weight of grains per earhead and grain yield.

On cultivation of bajra in the areas of limited soil moisture conditions or water availability, the application of phosphorus would enhance the water use efficiency as the level increased (Pyne *et al*., 1992). The observations on the field experiment conducted by Chejara *et al*. (2003) on pearl millet showed that there was significant enhancement in yield attributes as well as grain and stover yield with each increase in phosphorus level of 0-30 kg/ha.

Singh *et al*. (2017) showed that the application of phosphorus and zinc at the rate of 30 kg/ha and 20 kg/ha respectively improved the performance of pearl millet significantly in terms of plant height, number of tillers per plant, dry matter accumulation, grain yield, straw yield and harvest index of the crop over the other treatments of 10 kg/ha of P + 20 kg/ha of Zn, 20 kg/ha of P + 20 kg/ha of Zn and control. A pot culture study conducted in medium black calcareous soil revealed that there was significant improvement in the nutrient content and uptake by the crop by the application of chemical phosphatic fertilizers (Dhansil *et al*., 2018).

2.4 Effect of potassium on growth and yield of pearl millet

Research done by Ali and Prasad (1972) and Kanwar *et al*. (1973) in bajra showed a significant response to K application under rainfed conditions. Dayanand and Bapat (1976) recommended potassium application at 60 kg/ha to hybrid pearl millet along with N and P_2O_5 at 120 and 60 kg/ha to get better grain yield. The same trend was reported by Shekhawat *et al*. (1972) also from Rajastahan.

An experiment was conducted in dry areas under All India Co-ordinated Agronomic Research Project on medium and high K soils by Sharma *et al*. (1978) with pearl millet variety 'PHB 10' who concluded that the application of K_2O @15 kg/ha significantly increased the grain yield in both medium and high potassium soils. However, the response was more in medium than high K soils. The application of potassium (K_2O) at 15 kg/ha along with 60 kg/ha of N and 30 kg/ha of P_2O_5 gave increased yield of pearl millet under rainfed condition (Brar *et al*., 1980).

Lal (1980) found that N and P uptake by pearl millet was not influenced by levels of potassium. According to the study conducted by Sheta *et al*. (2010) the maximum green and dry forage yield of pearl millet variety 'GFB 1' increased by 10 per cent and 19 per cent by the basal application of potassium at the rate of 40 kg/ha. Sakarvadia *et al*. (2012) observed positive correlation of grain yield and plant height of pearl millet by the application of potassium at 120 kg/ha. However, higher stover yield and 1000 grain weight were associated with potassium application at 80 kg/ha.

2.5 Response of pearl millet to combined application of NPK fertilizers

Verma (1980) recommended the application of fertilizers to bajra @ 60 kg/ha of N along with 15-30 kg/ha P_2O_5 and K_2O to obtain the highest grain yield and stover yield of high yielding variety 'BJ 104'. Similarly, at Hisar higher productivity in pearl millet by the application of 100 kg/ha of N and 40 kg/ha P_2O_5 was reported by Taneja *et al*. (1981). The application of nitrogen @ 60 kg/ha and phosphorus @ 30 kg/ha improved the yield parameters of pearl millet (Malik *et al*., 1990).

There was significant improvement in the plant height and dry matter partitioning of the pearl millet by the application of recommended dose of 60 kg/ha N and 15 kg/ha P than lower level of N and P application (Sharma and Gupta, 2001). Zarafi *et al*. (2005) studied the effects of nitrogen and phosphorus on pearl millet and they observed that incidence and severity of the downy mildew of pearl millet varieties (Zango and GB8375) was suppressed significantly by the addition of nitrogen and phosphorus fertilizers.

Application of nitrogen and phosphorus fertilizers in pearl millet at 60 and 40 kg/ha respectively significantly enhanced the growth attributes, specifically plant height, total tillers per plant and dry matter accumulation over control (Rathore *et al*., 2006). According to Choudhary and Gautam (2007), the application of 60 kg/ha of N + 40 kg/ha of P_2O_5 along with FYM 10 t/ha and bio fertilizer gave significantly higher grain yield and N and P uptake by pearl millet over the control and FYM (5 or 10 t/ha) + bio fertilizers use.

The application of 80 kg/ha of N and 40 kg/ha of P_2O_5 gave greater grain yield of pearl millet than others due to more uptake of N and P, that helped better growth and development of the crop (Tetarwal and Rana, 2006). Girase *et al*. (2009) evaluated the response of pearl millet to different fertilizer levels in medium deep black soil under rainfed condition and they concluded that there was significant improvement in grain yield (35.27 q/ha), fodder yield (60.04 q/ha) and net returns (Rs. 12,756 per ha) with the application of 5 t/ha of FYM + 60: 30: 30 kg/ha NPK over other treatments.

A field study conducted by Kumar *et al*. (2014) showed a significant improvement in plant height, number of leaves, number of tillers per plant, days to 50% flowering, number of earheads per plant, length and width of earhead, grain weight per earhead, test weight and biological yield of pearl millet by the application of fertilizers at the rate of 40: 20: 20 kg/ha N: P_2O_5: K_2O.

The combined application of NPK at the rate of 100 kg N/ha, 30 kg P_2O_5/ha and 40 kg K_2O/ha in pearl millet resulted in higher crop production having highest dry matter production with better grain quality in sandy loam soils of southern zone of Andhra Pradesh (Reddy *et al*., 2016). An experiment conducted by Neha *et al*. (2017) in *zaid* season revealed that the application of fertilizers at 100: 45: 45 kg/ha N: P_2O_5: K_2O in pearl millet variety Pioneer 86 M 32 recorded higher grain yield, straw yield and yield parameters and more uptake of nitrogen, phosphorus and potassium with viable returns compared to other pearl millet varieties (Pro Agro 9444 and Ganga Kaveri 86 M 32).

Based on three years' study, Bhuva *et al*. (2018) reported that the application of 100 kg/ha nitrogen and 45 kg/ha phosphorus to pearl millet registered the highest crop yield and returns under rainfed condition of Gujarat. Krishnaprabu (2018) reported that judicious and balanced fertilizer application enhanced the productivity of pearl millet through the integration of organic manures along with chemical fertilizers.

Gautam *et al*. (2020) found that the height of bajra increased with increasing dose of nitrogen and phosphorus. Yield attributing characters also followed the same

pattern and the combined application of N and P (120 kg/ha and 60 kg/ha respectively) resulted in the highest grain yield and stover yield. According to Bhanuchandar *et al.* (2020), the application of N: P_2O_5: K_2O at 75: 40: 40 kg/ha was highly productive with higher yield parameters, maximum gross return, net return and B: C ratio under rainfed conditions.

2.6 Effect of fertilizers on nutrient content and uptake of pearl millet

According to Munda *et al*. (1984), NPK contents of bajra grains and stover increased significantly by increase in levels of application of nitrogen and phosphorus. The results from the experiment conducted on pearl millet at Rajasthan by Pareek and Shaktawat (1988) showed that there was significant improvement in uptake of nitrogen and phosphorus by the application of 60 kg/ha of phosphorus than 20 and 40 kg/ha.

NPK uptake and grain quality of pearl millet increased with the application of 5t/ha of FYM and 20 or 40 kg/ha of nitrogen (Verma, 1996). According to Jat *et al*. (2002), nitrogen content of pearl millet grain increased by the application of nitrogen at 60 and 90 kg/ha over 30 kg/ha and control. They also reported the maximum nitrogen content in stover when nitrogen was applied @ 90 kg/ha.

A field experiment was conducted at Haryana to study the nutrient uptake of pearl millet composites at four levels of nitrogen. Among these, the composite 'HC-10' recorded significantly higher K content in grain as well as total N, P and K uptake than the rest of the pearl millet composites except Raj 171 and MP 394. The N, P and K content in grain and uptake increased with increasing levels of N (Meena *et al*., 2003).

The highest NPK uptake in both grain and stover was registered with the application of 160 kg/ha nitrogen and 80 kg/ha phosphorus (Singh *et al*., 2006). The nitrogen, phosphorus and potassium contents in grain and stover of pearl millet as well as nutrient uptake was enhanced with the increase of the fertility level (Rathore, 2006). According to Singh (2006) also, in bajra NPK content and uptake were significantly affected by various fertility levels. Application of nitrogen at 120 kg/ha led to higher

uptake of N, P and K by grain and stover (71.74 kg/ha, 10.00 kg /ha and 13.147 kg /ha respectively in grain and 56.62 kg/ha, 6.14 kg /ha and 59.59 kg /ha respectively in stover) (Jadhav *et al*., 2011).

2.7 Effect of fertilizers on grain quality of pearl millet

The nutritive value of the bajra grains is fairly high with about 70 per cent carbohydrates, 12 per cent protein, 4.3-5.0 per cent fat, 2-7 per cent mineral matter and 2-4 per cent sugar. The grain is also rich in vitamins, thiamine and riboflavin content (Pal *et al*., 1996).

A field trial was conducted by Doesthale *et al*. (1972) to study the effect of nitrogen on amino acid content in grains of pearl millet and it was observed that with application of increasing nitrogen doses from 0 to 200 kg/ha, the protein content significantly improved along with the quality of the amino acids. However, lysine showed significant decrease.

The application of phosphorus @ 25 and 50 kg/ha significantly improved nitrogen, phosphorus and protein content of pearl millet grain over control (Yadav, 1990). NPK application enhanced the grain quality with the application of 5 t/ha of FYM along with 20 or 40 kg/ha of nitrogen (Verma, 1996).

An experiment conducted in acid soils of Sahel by Buerkert *et al*. (1998) revealed that the application of phosphorus significantly improved the concentration of phytic acid and phytate: zinc molar ratio in the grain due to the greater uptake of phosphorus as well as decreased the protein content of grains of pearl millet. The grain protein content was enhanced by the application of nitrogen @ 60 and 90 kg/ha than 30 kg/ha and control (Jat *et al*., 2002).

Yadavendra *et al*. (2003) indicated in their study that optimum nitrogen addition to pearl millet increased the metabolic energy and crude protein along with palatability and leaf -stem ratio. There was a significant improvement in the quality of bajra with maximum protein content of grain with increased level of application of nitrogen up to 100 kg/ha (Parihar *et al*. 2005). Dalal *et al*. (2005) also found that

protein content in grain of pearl millet got enhanced with increased rate of application of nitrogen fertilizers.

Ayub *et al*. (2007) noted that the balanced and judicious use of fertilizers significantly increased the yield parameters and quality parameters, especially protein content of pearl millet. Crude protein and crude fibre contents increased with increase in nitrogen levels, but ash content decreased. The response of different hybrids of pearl millet to different levels of nitrogen was studied by Kumari *et al*. (2017) who reported 13 per cent increase in protein content of grain by the supplementation of NPK at 100: 45: 45 kg/ha.

2.8 Growth, yield and quality parameters of pearl millet varieties

Several high yielding cultivars of pearl millet are available for cultivation in different parts of the country and the studies show that the growth parameters, quality attributes of grain, yield potential and fertilizer response of these varieties vary significantly. Pearl millet had a wide genetic variability from local varieties to various hybrids in their morphological traits, duration, characteristics, yield parameters along with the quality and quantity of grain and stover (Bidinger *et al*., 1994).

According to Munirathnam and Gautam (2002), the grain yield of bajra varieties Pusa 605 and Raj-171 was higher than Pusa Bajri 266 and ICMH 356. Yadav *et al*. (2003) observed that the pearl millet varieties were adapted to harsh growing conditions, while the hybrids performed well in areas with good irrigation facilities or with evenly distributed rainfall. Yadav *et al*. (2003) reported that the biomass accumulation of pearl millet was more in composites than hybrids and more amount of biomass was accumulated at 25 and 50 days after sowing.

Yadav *et al*. (2005) evaluated the performance of various hybrids and composites of bajra under rainfed conditions in Haryana. The grain yield of hybrids was 35 per cent more than the composites, whereas the fodder yield was 33 per cent more. The superiority in grain yield was attributed to the length of earheads, more effective tillers per plant and grain weight per earhead. Abedi *et al*. (2011) found that the variation in protein content was due to the genotypic characters of cultivars and

was also affected by soil moisture content and nitrogen application during the grain filling period of the crop. Meena *et al*. (2012) reported that the plant height of "Rajasthan Bajra Chari-2" was significantly higher than other varieties at all growth stages of the crop.

The study conducted at Agronomy farm of Rajiv Gandhi South Campus, Uttar Pradesh by Prasad *et al*. (2014) during *kharif* season concluded that the variety Pioneer 86M86 recorded significantly higher yield, yield attributes, nitrogen uptake and protein content compared to ICTP-8203 and Kaveri Super Boss. While ICTP-8203 recorded significantly higher 1000 grain weight over others, Kaveri Super Boss produced highest stover yield followed by Pioneer 86M86 and ICTP-8203.

Performance of Dhanashakti - a biofortified variety and ICTP 8203 were evaluated in All India Coordinated Pearl Millet Improvement Project (AICPMIP) to determine the iron and zinc contents along with agronomic performance. It was found that Dhanashakti had higher iron content of 81 ppm, 43 ppm of zinc, 11 per cent higher grain yield of 2.20 t/ha and 13 per cent higher dry fodder yield of 5.3 t/ha while comparing with ICTP 8203. But, both varieties were comparable with respect to duration of varieties (Rai *et al*., 2014).

The variety Dhanashakthi recorded highest amount of crude fibre (2.63 ±0.02 %) compared to other two varieties Shanti and Pioneer 86M64 (Kulthe *et al*., 2016). In a field experiment conducted by Divya *et al*. (2017) on sandy loam soils of Hyderabad, it was observed that the pearl millet variety PHB-3 showed better yield and yield attributes along with stover yield over the varieties ICMV-221 and Dhanashakti. After a field experiment in pearl millet, Neha *et al*. (2017) concluded that the variety Pioneer 86 M 32 showed better results with the highest seed yield (3.72 t/ha), NPK uptake of 223.3 kg/ha, 22.5 kg/ha and 347 kg/ha respectively, organic carbon (0.46 %) and high benefit cost ratio (2.65) along with the application of fertilizer at 100: 45: 45 kg/ha of NPK.

In an experiment conducted at ICAR - CSSRI, Makarana *et al*. (2017) found that the genotype AKVB-19 of pearl millet was superior compared to ICMV-15111 with

more grain production and higher grain quality under the conditions of saline environment of North Western region of India and hence suited to similar agro climatic conditions.

A study conducted by Manjanagouda *et al.* (2017) in red sandy loam soils of Karnataka revealed optimum green fodder production, dry matter yield, high NPK uptake and lower available soil nutrient status after harvest in bajra variety BAIF Bajra-1 over AVKB-19 and GFB-1. Chaudhari *et al*. (2018) studied the performance of different hybrids of pearl millet during summer season and found that higher grain and dry fodder yields along with higher values of growth attributes *viz*., plant height at 60 DAS and harvest, total tillers per plant was in hybrid GHB 558 as compared to GHB 744, GHB 538 and GHB 732.

Nayak *et al*. (2020) carried out an experiment during *kharif* season of 2019 to analyse the performance of pearl millet varieties and hybrids under rainfed condition with sixteen varieties/hybrids *viz*. HHB 229, AHB 1200, 86 M 01, NBH 5767, Pratap (MH 1662), NBH 4903, NBH 5061, 86 M 86, Kaveri Super Boss, 86 M 64, GHB 558, Dhanshakti, ICMV 221, Pusa Comp 612, ABV 04 and ICMV 155 in acidic sandy loamy soils of Odisha. The study concluded that Kaveri Super Boss registered the highest grain yield of 4667 kg/ha, which was statistically comparable with other two hybrids NBH 4903 (4536 kg/ha) and NBH 5061 (4195 kg/ha). The lowest grain yield was given by variety ICMV 155 (567 kg/ha) under rainfed conditions. Tallest plant (182 cm) and longest panicle was found in NBH 4903, maximum number of tillers was recorded in Kaveri Super Boss and Dhanashakti recorded highest test weight of 15.2 g.

Jayara and Reddy (2020) registered higher harvest index in hybrid Hanuman, which was on par with hybrid XB 20 plus over hybrid Vikas and concluded that it could be due to the variation in assimilate partitioning efficiency of hybrids. During *kharif* season of 2018, bajra variety ABV-04 gave a bumper yield with 10 quintals of grain yield even under 47 per cent of deficient rainfall recorded during the experimental period (Narasimhulu *et al*., 2020).

3. Materials and Methods

3. MATERIALS AND METHODS

The present research programme entitled “Response of high yielding varieties of pearl millet [*Pennisetum glaucum* (L.) R. Br.] to major nutrients” was carried out in AEU 10: North Central Laterites under Department of Agronomy, College of Agriculture, Vellanikkara during the period from November, 2020 to February 2021. The details of materials used and methods adopted for the study are presented in this chapter.

3.1 GENERAL DETAILS

1. Location

The study was conducted at Agronomy Farm, Department of Agronomy of College of Agriculture, Vellanikkara. The area comes under AEU 10: North Central Laterites. The North Central Laterites agro ecological unit is representing the midland laterite terrain with longer dry period than its southern part. The area covers 62 panchayats, three municipalities and two corporations of Thrissur and Palakkad districts. Geographically the area is located at 10°32'58"N latitude and 76°17'00"E longitude with an altitude of 40.3 m above Mean Sea Level.

2. Climate and weather conditions

The climate of the experimental site was tropical humid monsoon type. The average maximum temperature during the crop period was 33°C and minimum temperature was 21.7°C. The mean monthly averages of basic meteorological parameters observed during the experimental periods are presented in Figure 1 and Appendix 1.

3. Soil characteristics

The soil of the experimental site is sandy loam in texture. Soil samples were taken from 0 - 15 cm depth from different random spots of the experimental field prior to

layout and were subjected to physico-chemical properties of the soil. The basic physical and chemical properties of the soil are presented in Table 1.

Table 1. Physical and chemical properties of soil of experimental site

Parameters	Value	Method used
Chemical properties		
pH	4.74	1:2.5 soil water ratio (Jackson, 1958)
Electrical conductivity (dS/m)	0.23	
Organic carbon (%)	0.76 (Medium)	Walkley and Black method (Walkley and Black, 1934)
Available N (kg/ha)	124 (Low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg/ha)	66 (High)	Bray extractant- Ascorbic acid reductant method (Watanabe and Olsen, 1965)
Available K_2O (kg/ha)	218.16 (Low)	Neutral normal ammonium acetate extract using Flame Photometer (Jackson, 1958)

3.2 DETAILS OF THE EXPERIMENT

The experimental study was conducted at Agronomy Farm, Department of Agronomy of College of Agriculture, Vellanikkara, Thrissur.

1. Design and layout

The design used for the experiment was factorial RBD with 16 treatments and 3 replications. The plot size was 12 m^2 with spacing of 45 cm × 15 cm. The layout of the field is given in figure 2. Treatment parameters are listed below. The combination of varieties and N: P_2O_5: K_2O levels are the treatments used for the experiment. The varietal characteristics of selected varieties are presented in Table 2.

Treatment parameters

a) Pearl millet varieties

1. Co (Cu) 9
2. Co 10
3. ABV 04
4. Dhanashakthi

b) N: P_2O_5: K_2O levels (kg/ha)

1. 60: 30: 30
2. 70: 35: 35
3. 90: 45: 45
4. Absolute control

3.3 CROP PRODUCTION DETAILS

1. Land preparation

The land was ploughed and levelled to fine tilth. The experimental unit was divided into separate plots of $12m^2$ size according to the design and layout of the experiment.

2. Manuring and fertilizer application

Farm yard manure was incorporated into soil at the rate of 5 t/ha after the land separation into plots. One week after, lime was applied at the rate of 600 kg/ha and 10 days after of lime application, Factomphos, MOP and urea were used to supply primary nutrients. Urea was used for top dressing at 30 DAS. Entire quantity of phosphorus and potassium were applied in one dose as basal application.

3. Seed treatment and sowing

The seeds were treated with *Trichoderma viride* at 10 g/ kg of seeds in previous day of sowing as the dry seed treatment. The sowing was undertaken on 3rd November 2020 by dibbling in the lines on plots with seed rate of 5 kg/ha at a spacing of 45 cm × 15 cm.

Table 2. Characteristics of selected varieties

Sl. No.	Features	Co (Cu) 9	Co 10	ABV 04	Dhanashakthi
1.	**Year of release**	2005	2016	2019	2014
2.	**Institute**	AICPMIP, TNAU	AICPMIP, TNAU	ANGRAU, Ananthapuramu	ICRISAT, Hyderabad
3.	**Duration**	80-85 days	85-90 days	86 days	76 days
4.	**Grain yield**	2865 kg/ha	3767 kg/ha	2863 kg/ha	2199 kg/ha
5.	**Straw yield**	6000 kg/ha	5700 kg/ha	5800 kg/ha	5300 kg/ha
6.	**Earhead and grain characters**	Candle to cylindrical shaped, grey coloured with yellow base seed	Compact spindle shaped, grey brown bold seed	Thick and compact, grey coloured and bold seed	Cylindrical and lanceolate, bold, globular, shining and slate grey coloured seed

4. After cultivation practices

One week after germination, thinning was done manually from densely populated areas, gap filled and resowing was done in areas where seeds had not germinated. Hand weeding was done three times at 10, 20 and 30 DAS for keeping plots weed - free. The entire field area was covered with net to protect from birds.

5. Harvesting, drying and threshing

The crop was harvested in two steps, first by cutting the earheads according to their maturity and the straw was harvested after complete drying of plants from each plot. The harvested earheads were dried properly and threshed manually. Grains were weighed and winnowed. The straw was dried under sun and the weight of straw bundles as per the treatment was recorded.

3.4 RECORDED OBSERVATIONS

1. Biometric parameters

a) Plant height (cm)

Five plants were selected randomly from each treatment excluding the border plants and tagged. The plant height in cm was recorded by taking the height from ground level to the tip of longest leaf of plant at 30 days after sowing and at flowering stage.

b) Leaf blade length (cm) and width (cm)

The length and width of fifth or sixth leaf from bottom of the plant were measured from five plants of each plot at 30 DAS. Number of leaves per plant was also recorded from these selected plants.

c) Leaf Area Index (LAI)

Leaf area index is the ratio of leaf area to the plot area sampled. The leaf area was determined by measuring the leaf length and width along with the number of leaves from each plant randomly at 30 DAS.

$$\text{Leaf area} = \text{leaf length} \times \text{maximum width} \times k$$

Where, k is a constant (value of 0.75 is used as K)

d) Total number of tillers per plant

Total number of tillers per plant was counted at 30 DAS from five selected plants of each treatment plot.

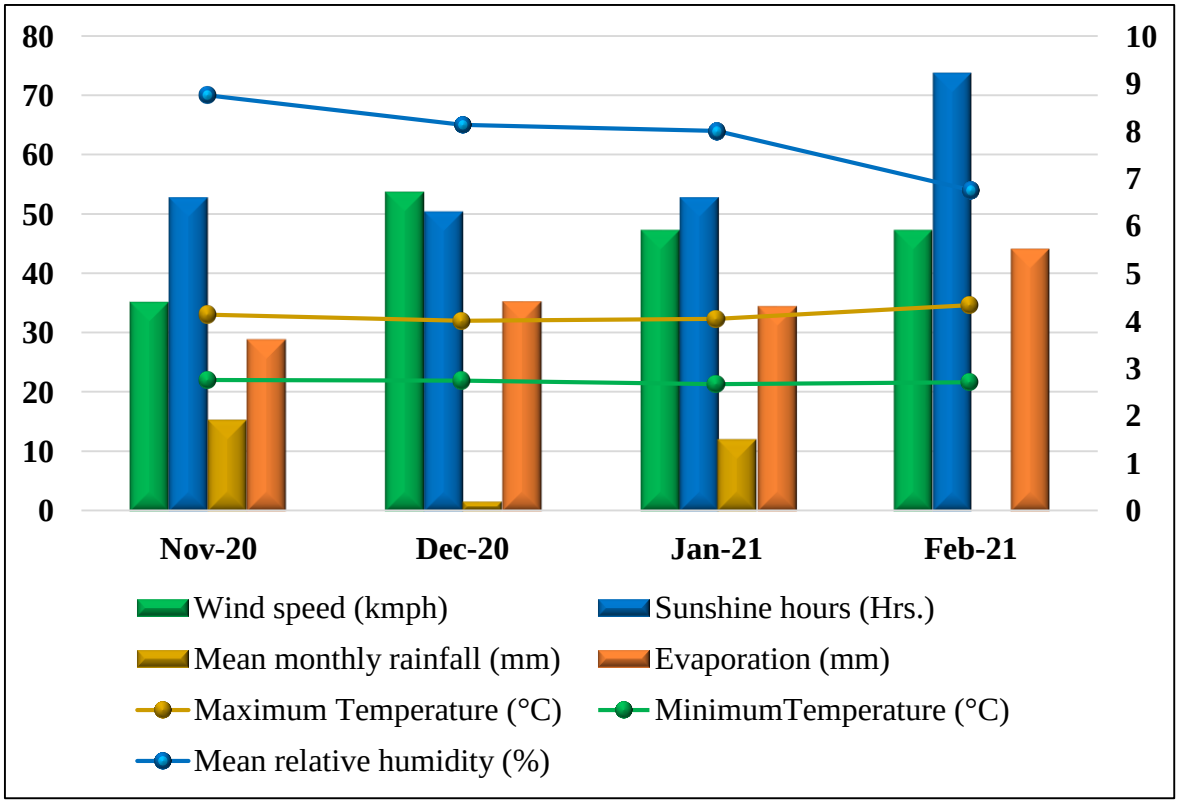
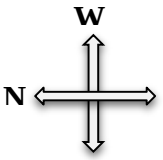


Figure 1. Monthly weather data during the experimental period
(November 2020- February 2021)



N_4 V_1	N_4 V_2	N_4 V_3	N_4 V_4
N_3 V_1	N_3 V_2	N_3 V_3	N_3 V_4
N_2 V_1	N_2 V_2	N_2 V_3	N_2 V_4
N_1 V_1	N_1 V_2	N_1 V_3	N_1 V_4

R_1

N_1 V_1	N_1 V_2	N_1 V_3	N_1 V_4
N_2 V_1	N_2 V_2	N_2 V_3	N_2 V_4
N_3 V_1	N_3 V_2	N_3 V_3	N_3 V_4
N_4 V_1	N_4 V_2	N_4 V_3	N_4 V_4

R_2

N_3 V_3	N_3 V_4	N_2 V_3	N_2 V_4
N_3 V_1	N_3 V_2	N_2 V_1	N_2 V_2
N_1 V_3	N_1 V_4	N_4 V_3	N_4 V_4
N_1 V_1	N_1 V_2	N_4 V_1	N_4 V_2

R_3

N: P_2O_5: K_2O levels	**Varieties**
N_1= 60:30:30 kg/ha	V_1= Co (Cu) 9
N_2= 70:35:35 kg/ha	V_2= Co 10
N_3=90:45:45 kg/ha	V_3= ABV 04
N_4= Absolute control	V_4= Dhanashakthi

Figure 2. Layout of the experimental plot

e) Dry matter production

Ten plants were uprooted at 30 DAS, flowering and harvesting stage from each treatment, cleaned, dried under shade and finally oven dried at 80 ± 5°C properly and dry weight was recorded in kg/ha to determine the periodical changes in dry matter accumulation of plants.

f) Days to 50% flowering

Days to 50 % flowering was observed for each variety on the stage when 50 % of plants in each plot were in anthesis.

g) Duration of varieties

According to the harvesting time of each variety of each treatment, the duration of varieties was noted.

2. Yield and yield attributes

a) Number of productive tillers per plant

The number of productive tillers per plant was counted in the tagged plants.

b) Earhead length (cm)

Ten earheads of bajra from each treatment were selected and the length from the basal end to the tip of the spikelet was measured and average value worked out.

c) Weight of grains per earhead (g)

Ten randomly sampled earheads from each plot were taken and dried, threshed, grains were separated, weighed and average worked out.

d) 1000 grain weight (g)

1000 grains were counted from random samples of threshed grains of every treatment and the test weight recorded in grams.

e) Grain yield (kg/ha)

The grain yield was recorded by harvesting total seeds from the experimental plots which were dried, threshed manually, winnowed and weighed the grains separately as per treatment in kg/plot and then converted into kg/ha.

f) Straw yield (kg/ha)

The tied bundles of straw were sun dried separately from each treatment plot, weighed in kg/plot and then converted to kg/ha.

g) Harvest index

Harvest index is the ratio of the grain yield (seed) to the sum of grain yield and straw yield (biological yield).

3. Quality parameters of grain

a) Crude protein (%)

Grain nitrogen content was estimated by using microkjeldhals digestion and distillation methods (Jackson, 1958) and the obtained value was multiplied with a factor of 6.25 to obtain crude protein content in grains.

b) Crude fiber (%)

By using alkali-acid digestion method, crude fiber of bajra grains was determined (Sadasivam and Manickam, 1992).

3.5 SOIL ANALYSIS

Soil sampling was done before sowing and after the harvest of the crop by following the standard procedure. The soil was drawn from 15 cm depth in random spots from each experimental unit and homogenized by quartering. The samples were dried, powdered and sieved by passing through 2mm sieve for most analysis and 0.5 mm sieve was used for organic carbon analysis. The chemical properties of pH, EC, organic carbon (%), available N, P, K (kg/ha) before and after the experiment was estimated using these samples. The methods used for the analysis are listed in Table 3.1.

3.6 PLANT ANALYSIS

At harvest, ten plants from each plot were collected, cleaned, dried under shade and oven dried at 60 ± 5°C for plant analysis. After drying, the plant samples were ground and packed properly and labelled. The nutrient content and uptake of nitrogen, phosphorus and potassium at harvest was analyzed. The methods used for plant analysis are given below.

Methods used for plant analysis

Nitrogen (%) : Microkjeldahl digestion and distillation method (Jackson, 1973)

Phosphorous (%) : Vanadomolybdate method by colorimetrically (Jackson, 1958)

Potassium (%) : Flame photometer (Jackson, 1958)

3.7 INCIDENCE OF PESTS AND DISEASES

Incidence of pests and diseases on pearl millet and nutrient deficiencies during the entire growth period of the crop was observed and recorded.

3.8 COST -BENEFIT ANALYSIS

The benefit- cost ratio was calculated by estimating the cost of cultivation, gross returns and benefits on the basis of the current market price of produce and inputs used for the experiment. The cost- benefit ratio was calculated by dividing the gross return with the total expenditure per hectare.

3.9 STATISTICAL ANALYSIS

The observed and estimated parameters were tabulated using Microsoft Excel spread sheet for data generation. The statistical analysis was done using analysis of variance with the statistical package OPSTAT (Gomez and Gomez, 1984).

Plate 1. Field preparation

Plate 2. Sowing

Plate 3. Different stages of reproductive phases

Plate 4. Field visit by Advisory Committee

4. Results

4. RESULTS

A field experiment entitled "Response of high yielding varieties of pearl millet to major nutrients" was carried out at Agronomy farm, Department of Agronomy of College of Agriculture, Vellanikkara. The observations on growth and yield attributes were analysed statistically and the findings are given in this chapter.

4.1 BIOMETRIC PARAMETERS

1. Plant height

Plant height was recorded at 30 days after sowing (DAS) and at flowering stage of the crop (Table 3). At 30 DAS, the plants that received N: P_2O_5: K_2O levels of 90: 45: 45 kg/ha, 70: 35: 35 kg/ha and 60: 30: 30 kg/ha registered statistically comparable plant height, which was superior to absolute control. The plant height was in the range of 81 cm to 99 cm at 30 DAS. However, by flowering stage there was a change in this trend. The plants which got higher fertilizer dose of 90: 45: 45 kg/ha N: P_2O_5: K_2O had taller plants (170 cm) and was at par with 70: 35: 35 kg/ha N: P_2O_5: K_2O (166 cm). The application of lower dose of N: P_2O_5: K_2O (60: 30: 30 kg/ha) as well as absolute control resulted in lower values of 152 cm and 151 cm respectively and both were comparable.

Among varieties, significant variation in plant height was observed. Co (Cu) 9 had a plant height of 102 cm and was comparable with Co 10 (95 cm) at 30 DAS. The lowest plant height was observed in ABV 04 (89 cm) and Dhanashakthi (86 cm), which were statistically comparable with Co 10 also. At flowering stage, the tallest variety was Co (Cu) 9 (180 cm). The next higher values were observed in varieties Co 10 and ABV 04 (163 cm and 154 cm respectively) and were at par. The variety Dhanashakthi was inferior in height compared with other varieties.

The interaction of N: P_2O_5: K_2O levels and varieties was not significant at all stages of observation with respect to plant height.

2. Total number of tillers per plant

The data on total number of tillers per plant observed at vegetative stage of 30 days after sowing is presented in Table 3. The count was taken from randomly selected five plants of each treatment. The plants which received various N: P_2O_5: K_2O levels registered statistically comparable values of total number of tillers with an average of 4.5 tillers per plant. Varietal differences as well as the interaction of N: P_2O_5: K_2O levels and varieties were also found to be non-significant.

Table 3. Plant height and total number of tillers per plant of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Plant height (cm)		Total number of tillers per plant
		30 DAS	Flowering	
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	93	152	4.42
N_2	70: 35: 35 kg/ha	99	166	5.00
N_3	90: 45: 45 kg/ha	99	170	4.67
N_4	Absolute control	81	151	4.08
CD (0.05)		**7.6**	**10.82**	**NS**
Varieties				
V_1	Co (Cu) 9	102	180	4.75
V_2	Co 10	95	163	4.33
V_3	ABV 04	89	154	4.50
V_4	Dhanashakthi	86	141	4.58
CD (0.05)		**7.6**	**10.82**	**NS**

3. Length and width of leaf blade

The length and width of leaf blade of pearl millet was measured at 30 days after sowing (Table 4). The application of various levels of N: P_2O_5: K_2O fertilizers resulted in an increase in the length and width of leaf blades compared to absolute control.

However, statistically comparable values were recorded for all applied amounts of N: P_2O_5: K_2O with an average length and width of 57.86 cm and 3.11 cm respectively. The lowest and statistically inferior value was observed in absolute control where no nutrients were supplied, with 51.02 cm length and 2.67 cm width.

There were considerable variations in between varieties. The leaf blade length varied from 51.83 cm in Dhanashakthi to 60.82 cm in Co (Cu) 9, which was statistically superior compared to other varieties. The varieties Co 10 and ABV 04 were statistically at par with respect to leaf length (55.4 cm and 56.54 cm respectively) and both were comparable to Dhanashakthi also. Dhanashakthi had a leaf width of 3.23 cm, which was superior to other varieties. The other three varieties registered comparable leaf width with an average value of 2.92 cm.

The interaction of N: P_2O_5: K_2O levels and varieties was not significant with respect to leaf blade length and width.

Table 4. Length, width of leaf blade and LAI of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Length of leaf blade (cm)	Width of leaf blade (cm)	Leaf Area Index
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	57.40	3.05	3.81
N_2	70: 35: 35 kg/ha	58.35	3.15	3.84
N_3	90: 45: 45 kg/ha	57.83	3.14	3.96
N_4	Absolute control	51.02	2.67	2.94
CD (0.05)		**3.89**	**0.21**	**0.33**
Varieties				
V_1	Co (Cu) 9	60.82	2.99	4.71
V_2	Co 10	55.4	2.92	3.96
V_3	ABV 04	56.54	2.84	3.21
V_4	Dhanashakthi	51.83	3.23	2.70
CD (0.05)		**3.89**	**0.21**	**0.33**

4. Leaf Area Index

Leaf Area Index (LAI) was computed and presented in Table 4. There was an increase in LAI of the plants by the application of different N: P_2O_5: K_2O levels. However, different doses of N: P_2O_5: K_2O recorded a comparable LAI with an average value of 3.87. Absolute control had the lowest index of 2.94, which was inferior to all other N: P_2O_5: K_2O levels.

When compared to the other three varieties, Co (Cu) 9 had the highest Leaf Area Index of 4.71 followed by Co 10 (3.96). Statistically inferior value of Leaf Area Index was registered for Dhanashakthi (2.7). The interaction of N: P_2O_5: K_2O levels and varieties on Leaf Area Index was found to be non-significant.

5. Leaf – Stem ratio

The leaf - stem ratio of pearl millet varieties as influenced by various N: P_2O_5: K_2O levels was recorded during the active growth phase (60 DAS) and the data are given in Table 5. There was no significant variation in leaf - stem ratio by the application of varied N: P_2O_5: K_2O levels, which were statistically comparable with an average ratio of 0.24.

The varieties significantly differed from each other in leaf - stem ratio. The highest leaf - stem ratio was registered in Dhanashakthi, which was statistically superior (0.28). The leaf -stem ratio was 0.21 in Co (Cu) 9 which was inferior to all varieties.

The interaction effect of N: P_2O_5: K_2O levels and varieties was significant. In variety Dhanashakthi, the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O and 90: 45: 45 kg/ha N: P_2O_5: K_2O resulted superior in leaf – stem ratio, that were at par. The lowest value registered in Co (Cu) 9 with the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O, which was statistically inferior. In case of 60: 30: 30 kg/ha N: P_2O_5: K_2O, the varieties ABV 04 and Dhanashakthi performed better and both were at par.

Table 5. Leaf-stem ratio of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments	Leaf – stem ratio of bajra varieties				
N: P_2O_5: K_2O levels	Co (Cu) 9 (V_1)	Co 10 (V_2)	ABV 04 (V_3)	Dhanashakthi (V_4)	**Mean**
60: 30: 30 kg/ha (N_1)	0.21	0.23	0.26	0.26	0.24
70: 35: 35 kg/ha (N_2)	0.20	0.23	0.25	0.30	0.24
90: 45: 45 kg/ha (N_3)	0.22	0.23	0.25	0.29	0.25
Absolute control (N_4)	0.22	0.22	0.23	0.26	0.23
Mean	0.21	0.23	0.25	0.28	

CD (p=0.05) of N: P_2O_5: K_2O levels: **NS**

CD (p=0.05) of varieties: **0.01**

CD (p=0.05) of N: P_2O_5: K_2O levels X varieties interaction: **0.02**

6. Days to 50% flowering

There was not much variation in days to 50% flowering with respect to different levels of N: P_2O_5: K_2O fertilizers applied (Table 6). On an average 42 days were required to attain 50 per cent flowering in pearl millet. However, the varietal differences were significant.

The variety Co (Cu) 9 took longer duration (47 days) to reach 50 per cent flowering compared to others. This was followed by Co 10 (43.50 days), ABV 04 (41 days). Dhanashakthi was earlier in flowering and 50 % of the spikelets reached anthesis by 38 days. The interaction between N: P_2O_5: K_2O levels and varieties was not significant.

Table 6. Days to 50 % flowering and harvest of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Days to 50% flowering	Days to harvest (days)
N: P_2O_5: K_2O levels			
N_1	60: 30: 30 kg/ha	43	70
N_2	70: 35: 35 kg/ha	41.50	70
N_3	90: 45: 45 kg/ha	42	69
N_4	Absolute control	43	70
CD (0.05)		**0.74**	**NS**
Varieties			
V_1	Co (Cu) 9	47	79
V_2	Co 10	43.50	71
V_3	ABV 04	41	66
V_4	Dhanashakthi	38	63
CD (0.05)		**0.74**	**0.52**

7. Days to harvest

The influence of different N: P_2O_5: K_2O levels on duration of pearl millet was not significant (Table 6). However, the varieties differed significantly from each other with respect to the duration or days to harvest. Among varieties, Dhanashakthi reached to harvest stage significantly earlier (63 days) while Co (Cu) 9 reached harvest stage in 79 days. The duration of the varieties Co 10 and ABV 04 were 71 days and 66 days respectively. The interaction of N: P_2O_5: K_2O levels and varieties was not significant.

8. Dry matter production (kg/ha)

The dry matter production was recorded at 30 DAS, flowering and at harvest (Table 7). N: P_2O_5: K_2O application resulted in an increased dry matter production at different stages of plant growth.

Application of 70: 35: 35 kg/ha N: P_2O_5: K_2O (779 kg/ha) was comparable with 90: 45: 45 kg/ha N: P_2O_5: K_2O (647 kg/ha) in dry matter production at 30 DAS. Lower dry matter production was noticed in absolute control with 508 kg/ha. Though the varietal differences were statistically significant, except Dhanashakthi all others registered statistically comparable dry matter production at 30 DAS.

At flowering stage, statistically significant accumulation could be observed by the application of varying N: P_2O_5: K_2O levels. The dry matter production with the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O was 3,280 kg/ha which was superior to lower levels. The comparable dry matter production observed in plants which got 70: 35: 35 kg/ha N: P_2O_5: K_2O and 60: 30: 30 kg/ha N: P_2O_5: K_2O with an average of 2714. 5 kg/ha followed by absolute control.

While assessing different varieties, Co (Cu) 9 had the highest dry matter production (3,212 kg/ha) followed by Co 10 (2,938 kg/ha). The varieties ABV 04 and Dhanashakthi produced statistically lower dry matter yields (2,504 and 2,294 kg/ha respectively) and both were comparable.

At harvest, there was statistically significant accumulation influenced by varying N: P_2O_5: K_2O levels. The dry matter production was 12,555 kg/ha by the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O was the highest. This was followed by the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O and 60: 30: 30 kg/ha N: P_2O_5: K_2O, both of which were comparable. Absolute control registered the lowest value. The varieties Co (Cu) 9 (12,289 kg/ha) and ABV 04 (11,215 kg/ha) had the highest dry matter production which were statistically comparable to Co 10. The variety Dhanshakthi continued to register the lower dry matter production at harvest stage also.

The interaction of N: P_2O_5: K_2O levels and varieties was found to be non-significant at different stages of plant growth.

Table 7. Dry matter production of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Dry matter production (kg/ha)		
		30 DAS	Flowering	Harvest
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	579	2,629	10,392
N_2	70: 35: 35 kg/ha	779	2,800	11,396
N_3	90: 45: 45 kg/ha	647	3,280	12,555
N_4	Absolute control	508	2,239	8,474
CD (0.05)		**153**	**240**	**1,105.5**
Varieties				
V_1	Co (Cu) 9	713	3,212	12,289
V_2	Co 10	776	2,938	10,875
V_3	ABV 04	584	2,504	11,215
V_4	Dhanashakthi	440	2,294	8,437
CD (0.05)		**153**	**240**	**1,105.5**

4.2 YIELD AND YIELD ATTRIBUTES

1. Number of productive tillers per plant

Number of productive tillers of a plant observed at active reproductive phase of the plant (60 DAS) is furnished in Table 8. The number of productive tillers was found to be non-significant when various N: P_2O_5: K_2O levels were applied to pearl millet varieties. The average number of productive tillers per plant was 4.50. The four varieties also showed a comparable number of productive tillers per plant (4.5 tillers/plant). The interaction of N: P_2O_5: K_2O levels and varieties was also not significant.

2. Earhead length

Earhead length was not influenced by the application of different N: P_2O_5: K_2O fertilizers (Table 8). The average length of earhead was 22.60 cm. However, in case of

varieties, statistically significant variation was observed. The longest earhead (26.62 cm) was observed in the variety Co (Cu) 9. Co 10 (22.91 cm) and ABV 04 (21.47 cm) were at par. The shortest and statistically inferior earhead length was in Dhanashakthi (19.44 cm). The interaction of N: P_2O_5: K_2O levels and varieties was not significant.

Table 8. Yield attributes of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Number of productive tillers per plant	Earhead length (cm)	Weight of grains per earhead (g)	1000 grain weight (g)
N: P_2O_5: K_2O levels					
N_1	60: 30: 30 kg/ha	4.33	22.17	31.82	10.33
N_2	70: 35: 35 kg/ha	4.67	22.45	32.40	11.80
N_3	90: 45: 45 kg/ha	4.92	23.16	36.93	12.89
N_4	Absolute control	4.17	22.62	30.18	9.71
CD (0.05)		**NS**	**NS**	**4.34**	**0.73**
Varieties					
V_1	Co (Cu) 9	4.58	26.62	29.27	7.99
V_2	Co 10	4.33	22.91	32.51	11.03
V_3	ABV 04	4.33	21.47	34.31	12.35
V_4	Dhanashakthi	4.83	19.44	35.24	13.35
CD (0.05)		**NS**	**1.03**	**4.34**	**0.73**

3. Weight of grains per earhead

The application of different N: P_2O_5: K_2O levels had a significant influence on weight of grains per earhead (Table 8). The N: P_2O_5: K_2O level of 90: 45: 45 kg/ha gave the highest value of 36.93 g, which was superior to others. The other two N: P_2O_5: K_2O levels as well as absolute control had comparable weight of grains with an average of 31.47 g per earhead.

Among varieties, Co 10, ABV 04 and Dhanashakthi were at par with an average of 34.02 g. The lowest weight of grains was in the variety Co (Cu) 9 (29.27 g). The interaction of N: P_2O_5: K_2O levels and varieties were also found to be non-significant.

4. 1000 grain weight

There was a statistical difference in 1000 grain weight as influenced by different N: P_2O_5: K_2O levels (Table 8). As the N: P_2O_5: K_2O levels increased, test weight showed an increasing trend. Application of 90: 45: 45 kg/ha N: P_2O_5: K_2O and 70: 35: 35 kg/ha N: P_2O_5: K_2O resulted a comparable test weight of 12.89 g and 11.80 g respectively. The level of 60: 30: 30 kg/ha N: P_2O_5: K_2O (10.33 g) and absolute control (9.71 g) were at par.

Among four varieties, 1000 grain weight ranged from 7.99 g in Co (Cu) 9 to 13.35 g in Dhanashakthi. The variety Dhanashakthi and ABV 04 were superior to other two varieties. The least test weight was registered in Co (Cu) 9. The interaction of N: P_2O_5: K_2O levels and varieties was not significant.

5. Grain yield

The grain yield at different doses of N: P_2O_5: K_2O application statistically differed from each other (Table 9). The addition of primary nutrients boosted the grain yield compared to no application. Superior grain yield of 3360 kg/ha resulted by the addition of N: P_2O_5: K_2O level of 90: 45: 45 kg/ha. Application of 70: 35: 35 and 60: 30: 30 kg/ha N: P_2O_5: K_2O yielded the next best grain yield (3,107 kg/ha and 2,700 kg/ha respectively), whereas lowest yield of 2,323 kg/ha was recorded in absolute control.

Three varieties ABV 04, Co 10 and Dhanashakthi were comparable with respect to grain yield and were superior to variety Co (Cu) 9. The variety Co (Cu) 9 registered yield of 2,201 kg/ha. The interaction of different N: P_2O_5: K_2O levels and pearl millet varieties was not significant.

6. Straw yield

Significant difference could be observed in straw yield with various N: P_2O_5: K_2O levels (Table 9). The straw yield was 10,753 kg/ha in 70: 35: 35 kg/ha N: P_2O_5: K_2O

and that was statistically comparable to 90: 45: 45 kg/ha N: P_2O_5: K_2O (10,391 kg/ha). The straw yield in absolute control and 60: 30: 30 kg/ha N: P_2O_5: K_2O was 6,670 kg/ha and 8,293 kg/ha respectively, both were at par.

The varietal differences were statistically significant. The superior yield was registered in Co (Cu) 9 (11,390 kg/ha) was on par with straw yield of ABV 04 (10,191 kg/ha). The lower straw yield of 6,430 kg/ha was noticed in variety Dhanashakthi and comparable to Co 10 (8,096 kg/ha). The interaction of pearl millet varieties with N: P_2O_5: K_2O levels was not significant.

Table 9. Grain yield, straw yield and harvest index of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	2,700	8,293	0.26
N_2	70: 35: 35 kg/ha	3,107	10,753	0.24
N_3	90: 45: 45 kg/ha	3,360	10,391	0.26
N_4	Absolute control	2,323	6,670	0.27
CD (0.05)		**248**	**1,705**	**NS**
Varieties				
V_1	Co (Cu) 9	2,201	11,390	0.17
V_2	Co 10	3,075	8,096	0.28
V_3	ABV 04	3,188	10,191	0.25
V_4	Dhanashakthi	3,026	6,430	0.34
CD (0.05)		**248**	**1,705**	**0.04**

7. Harvest index

The addition of different levels of N: P_2O_5: K_2O did not affect the harvest index, which was statistically non-significant with an average of 0.29 (Table 9).

In the case of varieties, harvest index varied. Dhanashakthi recorded highest and superior HI of 0.34. The next best were Co 10 and ABV 04 with a mean value of 0.27, and both were on par. The least HI was registered in Co (Cu) 9 with only 0.17. Here also, the interaction of N: P_2O_5: K_2O levels and pearl millet varieties was not significant statistically.

4.3 QUALITY PARAMETERS OF GRAIN AT HARVEST

1. Crude protein

Crude protein content in grain of pearl millet varieties as influenced by N: P_2O_5: K_2O levels found to be significant and data is given in Table 10. The addition of different N: P_2O_5: K_2O levels had a significant effect in crude protein per cent compared to absolute control. Among nutrient levels, the greatest N: P_2O_5: K_2O level of 90: 45: 45 kg/ha resulted the highest crude protein content in grain of 13.03 per cent, which was superior to the other levels. Other N: P_2O_5: K_2O levels as well as absolute control registered statistically comparable values of crude protein. The range was 10 to 11.39 %.

The average value of crude protein was 11.37 % among varieties and the varietal differences were non-significant. The interaction of different N: P_2O_5: K_2O levels and varieties was found to be non-significant.

2. Crude fibre

The application of different N: P_2O_5: K_2O fertilizers slightly influenced the crude fibre content of pearl millet grains over no fertilizer application (Table 10). Crude fibre per cent obtained by the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O was comparable to other levels of 70: 35: 35 kg/ha N: P_2O_5: K_2O and 60: 30: 30 kg/ha N: P_2O_5: K_2O with an average of 2.29%. Whereas, the two lower N: P_2O_5: K_2O levels were on par with absolute control.

In case of varieties, crude fibre content was statistically comparable in ABV 04, Dhanashakthi and Co (Cu) 9 with an average content of 2.33 %. The crude fibre per

cent of the variety Co 10 was 1.82 %. The interaction of different N: P_2O_5: K_2O levels and varieties was not significant.

Table 10. Crude fibre and crude protein content in grain of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Treatments		Crude protein (%)	Crude fibre (%)
N: P_2O_5: K_2O levels			
N_1	60: 30: 30 kg/ha	11.03	2.10
N_2	70: 35: 35 kg/ha	11.39	2.13
N_3	90: 45: 45 kg/ha	13.03	2.64
N_4	Absolute control	10.00	1.93
CD (0.05)		**1.43**	**0.30**
Varieties			
V_1	Co (Cu) 9	11.18	2.19
V_2	Co 10	10.94	1.82
V_3	ABV 04	11.67	2.43
V_4	Dhanashakthi	11.67	2.38
CD (0.05)		**NS**	**0.30**

4.4 SOIL ANALYSIS

1. pH

The pH of soil did not vary significantly with respect to the N: P_2O_5: K_2O levels and varieties of bajra (Table 11). The initial pH of the soil was 4.74 and there was a slight variation of pH observed in various treatments of different N: P_2O_5: K_2O levels. All were statistically on par with an average pH of 4.92.

In case of varieties, the mean pH was 5.02 which were comparable. The interaction of different N: P_2O_5: K_2O levels and varieties was not significant to change in pH of soil.

2. EC

The electrical conductivity of the soil also was found to be non-significant with respect to N: P_2O_5: K_2O levels and four varieties (Table 11). Before the experiment, the EC was 0.23 dS/meter. The plants which received different N: P_2O_5: K_2O levels showed a statistically on par EC values with an average of 0.073 dS/m.

Table 11. pH, EC and organic carbon of the soil after the experiment as influenced by N: P_2O_5: K_2O levels

Treatments		pH	EC (dS/m)	Organic carbon (%)
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	5.14	0.081	0.84
N_2	70: 35: 35 kg/ha	4.90	0.070	1.07
N_3	90: 45: 45 kg/ha	4.98	0.079	1.11
N_4	Absolute control	4.67	0.062	0.72
CD (0.05)		**NS**	**NS**	**0.20**
Varieties				
V_1	Co (Cu) 9	5.12	0.056	0.88
V_2	Co 10	4.91	0.083	0.86
V_3	ABV 04	5.22	0.069	1.05
V_4	Dhanashakthi	4.83	0.083	0.85
CD (0.05)		**NS**	**NS**	**NS**

3. Organic carbon (%)

The organic carbon content of the soil showed significant difference with respect to N: P_2O_5: K_2O fertilizer application and was non-significant with respect to varieties and the interaction effect (Table 11). There was an increase in organic carbon content from 0.72 % to 1.11 % with respect to N: P_2O_5: K_2O levels. The application of 90: 45: 45 kg/ha and 70: 35: 35 kg/ha N: P_2O_5: K_2O levels to the soil registered comparable values. No fertilizer application as well as the application of lower dose of 60: 30: 30

kg/ha N: P_2O_5: K_2O registered lower and comparable values. There was no significant variation in organic carbon with respect to different varieties.

4. Available nitrogen content

The available nitrogen content of the soil was estimated after the harvest and was found to be non-significant with respect to different N: P_2O_5: K_2O levels, varieties and their interaction (Table 12). The available N status before the experiment was 124 kg/ha. The values of available N ranged from 129 kg/ha in absolute control to 165 kg/ha in the case of 90: 45: 45 kg/ha N: P_2O_5: K_2O application.

Table 12. Available NPK content of the soil after the experiment as influenced by N: P_2O_5: K_2O levels

Treatments		Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	144	79	240
N_2	70: 35: 35 kg/ha	152	95	246
N_3	90: 45: 45 kg/ha	165	107	287
N_4	Absolute control	129	65	222
CD (0.05)		**NS**	**16**	**NS**
Varieties				
V_1	Co (Cu) 9	157	95	234
V_2	Co 10	153	83	258
V_3	ABV 04	154	82	265
V_4	Dhanashakthi	149	85	239
CD (0.05)		**NS**	**NS**	**NS**

5. Available phosphorus content

A significant change in available phosphorus content of soil was noticed with respect to different N: P_2O_5: K_2O levels and there was no change in the case of different

varieties (Table 12). There was no change in phosphorus content from initial status of 66 kg/ha in the case of absolute control, which registered a value of 65 kg/ha after the harvest of the crop. Phosphorus status was enhanced by the application of phosphorus fertilizers. The available P obtained by the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O (107 kg/ha) was on par with 70: 35: 35 kg/ha (95 kg/ha) and 60: 30: 30 kg/ha (79 kg/ha). The least available phosphorus observed in absolute control was comparable that at 70: 35: 35 kg/ha N: P_2O_5: K_2O and 60: 30: 30 kg/ha N: P_2O_5: K_2O. The interaction of N: P_2O_5: K_2O levels and varieties was not significant.

6. Available potassium content

The available potassium content of the soil after the harvest found to be non-significant with respect to N: P_2O_5: K_2O levels and varieties (Table 12). The available potassium status prior to experiment was 218 kg/ha. There was a slight variation in available K content of the soil in application of various potassium fertilizers. All were statistically on par with an average of 245 kg/ha and 249 in the case of different N: P_2O_5: K_2O levels and varieties respectively. The interaction of N: P_2O_5: K_2O levels and varieties was not significant.

4.5 PLANT ANALYSIS

1. Nutrient uptake at harvest

The content of nitrogen, phosphorus and potassium was analysed using the plant samples and grain samples from each treatment after the harvest. The application of different N: P_2O_5: K_2O levels had a significant influence on nutrient uptake at harvest (Table 13). Varietal differences were also significant.

The highest and superior nitrogen uptake was recorded in the plants that got 90: 45: 45 kg/ha N: P_2O_5: K_2O (437 kg/ha). Other two N: P_2O_5: K_2O levels were found to be comparable with an average N uptake of 330 kg/ha. Phosphorus uptake was the highest with the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O (126 kg/ha) and that was on par to 70: 35: 35 kg/ha N: P_2O_5: K_2O level. Potassium uptake was comparable at different N: P_2O_5: K_2O levels with an average of 358 kg/ha. In absolute control, the

uptake of primary nutrients was very less compared to other treatments (215 kg/ha of N, 48 kg/ha of P and 267 kg/ha of K).

Table 13. Nutrient uptake of pearl millet varieties at harvest as influenced by N: P_2O_5: K_2O levels

Treatments		N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
N: P_2O_5: K_2O levels				
N_1	60: 30: 30 kg/ha	314	88	339
N_2	70: 35: 35 kg/ha	346	103	341
N_3	90: 45: 45 kg/ha	437	126	395
N_4	Absolute control	215	48	267
CD (0.05)		**31**	**15.5**	**61.50**
Varieties				
V_1	Co (Cu) 9	382	90	372
V_2	Co 10	322	79	331
V_3	ABV 04	339	101	366
V_4	Dhanashakthi	268	95	273
CD (0.05)		**31**	**15.5**	**61.50**

Among varieties, there was only a slight difference with respect to nitrogen uptake. The N uptake of variety Co (Cu) 9 (382 kg/ha) was comparable with ABV 04 (339 kg/ha) and Co 10 (322 kg/ha). The lowest uptake was in Dhanashakthi (268 kg/ha), however it was found to be on par with Co 10.

The varieties Co (Cu) 9, ABV 04 and Dhanashakthi were on par in phosphorus uptake followed by Co 10 (79 kg/ha). There was comparable potassium uptake in ABV 04, Co (Cu) 9 and Co 10 with 356 kg/ha uptake on an average. Whereas, Dhanashakthi recorded lesser K uptake of 273 kg/ha. The interaction of different N: P_2O_5: K_2O levels and varieties was found to be non-significant.

4.6 INCIDENCE OF PESTS AND DISEASES

There was no severe incidence of pests and diseases during the crop period. Some minor pests and diseases were observed. Mild incidence of sheath rot and leaf blight was observed at vegetative stage. The observed pests were leaf roller, epilachna beetle and grass hopper. No plant protection chemicals were applied as the incidence of pests and diseases were mild.

4.7 COST BENEFIT ANALYSIS

Total cost of the production varied with respect to different N: P_2O_5: K_2O levels applied (Table 14). The cost were Rs. 66750 per ha, Rs. 68241 per ha, Rs. 76400 per ha and Rs. 60500 per ha in the case of different N: P_2O_5: K_2O levels of 60: 30: 30 kg/ha, 70: 35: 35 kg/ha, 90: 45: 45 kg/ha and absolute control respectively.

The range of gross returns was from Rs. 74,336 per ha in absolute control for variety Co (Cu) 9 to Rs. 145,689 per ha in the case of 90: 45: 45 kg/ha N: P_2O_5: K_2O for variety ABV 04. Among net returns, highest and superior net return was obtained from the treatment combination of 70: 35: 35 kg/ha N: P_2O_5: K_2O in ABV 04 and which was almost comparable with 90: 45: 45 kg/ha N: P_2O_5: K_2O in ABV 04. The lowest net returns resulted from absolute control, where no nutrients were added.

By comparing Benefit- Cost ratio of the production, the highest ratio of 2.03 registered in N: P_2O_5: K_2O level of 70: 35: 35 kg/ha N: P_2O_5: K_2O in variety ABV 04. This was followed by 90: 45: 45 kg/ha N: P_2O_5: K_2O for variety ABV 04, 70: 35: 35 kg/ha N: P_2O_5: K_2O in Co 10, 60: 30: 30 kg/ha N: P_2O_5: K_2O in ABV 04 and 90: 45: 45 kg/ha N: P_2O_5: K_2O in Co 10. The lowest ratio recorded in absolute control for variety Co (Cu) 9 followed by 60: 30: 30 kg/ha N: P_2O_5: K_2O in Co (Cu) 9. The application of fertilizers enhanced the benefit- cost ratio of the varieties.

Table 14. Cost-Benefit analysis of pearl millet cultivation

Treatments		Cost and returns (Rs. /ha)					
N: P_2O_5: K_2O levels (kg/ha)	Varieties	Total cost	Returns		Gross returns	Net returns	B:C ratio
			Grains	Straw			
60: 30: 30	Co (Cu) 9	66,750	63,590	25,949	89,539	22,789	1.34
	Co 10		81,540	21,066	102,606	35,856	1.54
	ABV 04		88,730	26,582	115,312	48,562	1.73
	Dhanashakthi		90,192	13,399	103,591	36,841	1.55
Mean		**66,750**	**81,013**	**21,749**	**102,762**	**36,012**	**1.54**
70: 35: 35	Co (Cu) 9	68,241	70,960	37,782	108,742	40,501	1.59
	Co 10		99,170	24,816	123,986	55,745	1.82
	ABV 04		108100	30,232	138,332	70,091	2.03
	Dhanashakthi		94,656	19,991	114,647	46,406	1.68
Mean		**68,241**	**93,222**	**28,205**	**121,427**	**53,186**	**1.78**
90: 45: 45	Co (Cu) 9	76,400	79,420	31,582	111,002	34,602	1.45
	Co 10		107310	22,716	130,026	53,626	1.70
	ABV 04		111890	33,799	145,689	69,289	1.91
	Dhanashakthi		104580	20,983	125,563	49,163	1.64
Mean		**76,400**	**100800**	**27,270**	**1,28,070**	**51,670**	**1.70**
Absolute control	Co (Cu) 9	60,500	50170	24,166	74,336	13,836	1.23
	Co 10		80990	16,365	97,355	36,855	1.61
	ABV 04		73880	16,333	90,213	29,713	1.49
	Dhanashakthi		73656	11,466	85,122	24,622	1.41
Mean		**60,500**	**69,674**	**17,083**	**86,757**	**26,257**	**1.44**

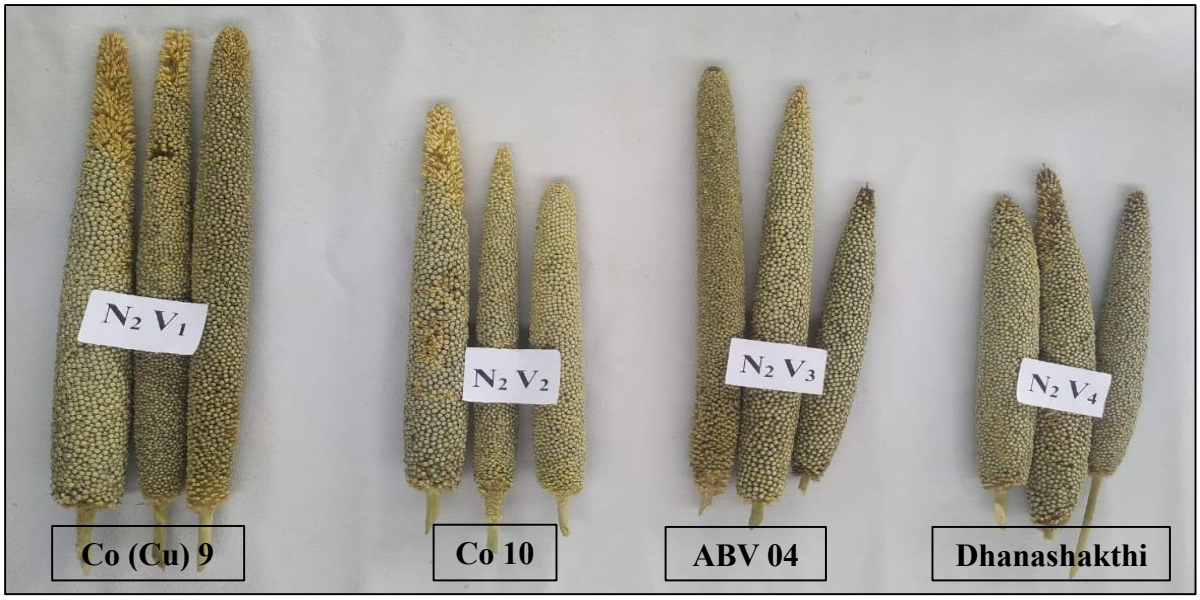


Plate 5. Varietal differences in earhead characteristics

Plate 6. Varietal differences in grain characteristics

5. Discussion

5. DISCUSSION

The results of the field experiment conducted on "Response of high yielding varieties of pearl millet to major nutrients" is discussed in this chapter with the help of supporting scientific literature. The treatments in the study were the application of different N: P_2O_5: K_2O levels, 60: 30: 30 kg/ha (N_1), 70: 35: 35 kg/ha (N_2), 90: 45: 45 kg/ha (N_3) and absolute control (N_4) and four pearl millet varieties - Co (Cu) 9 (V_1), Co 10 (V_2), ABV 04 (V_3) and Dhanashakthi (V_4). The soil of the experimental field was medium in organic carbon and low in available nitrogen and potassium, whereas available phosphorus status was high.

5.1 Biometric parameters of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

The overall improvement in growth parameters *viz.* plant height, length and width of leaf blade, Leaf Area Index, days to 50% flowering and dry matter production of pearl millet varieties were observed with the application of varied doses of N: P_2O_5: K_2O fertilizer. This could possibly be attributed to the balanced nutritional environment in the rhizosphere which led to more absorption of nutrients and hence plant growth. The vegetative growth of pearl millet was shown to be much influenced by the fertility status of soil where the crop is grown (Mahalakshmi *et al*., 1987). This would be due to better root development as a result of the effective utilization of the primary nutrients. These nutrients play a major role in cell division as well as cell elongation and the optimum availability increased the photosynthetic area that cumulatively contributed to higher vegetative growth. Jain and Dahama (2006) reported that the efficient utilization of nutrients through the extensive root system developed by adequate phosphorus application helped in better growth of bajra.

The plants that received different N: P_2O_5: K_2O levels of 90: 45: 45 kg/ha, 70: 35: 35 kg/ha and 60: 30: 30 kg/ha registered statistically comparable plant height at 30 DAS (81 - 99 cm), whereas no fertilizer application resulted in a reduction in plant height due to poor availability of nutrients for plant growth (Table 3 and figure 3). However at

flowering stage, the plants which got higher fertilizer dose of 90: 45: 45 kg/ha N: P_2O_5: K_2O had taller plants (170 cm) and was at par with 70: 35: 35 kg/ha N: P_2O_5: K_2O (166 cm). This indicated that probably the plant is unable to utilize higher quantity of nutrients resulting in poor nutrient use efficiency. It was also seen that the lower dose of 60: 30: 30 kg/ha N: P_2O_5: K_2O and no fertilizer application resulted in comparable plant height. Ayub *et al*. (2007) reported there was an increase in plant height from 160 to 229 cm with the application of increased nitrogen levels up to 100 kg/ha whereas at 150 kg N/ha, a significant decrease in plant height was noticed due to imbalanced nutrient availability of the soil. Gautam *et al*. (2020) found that the phosphorus application up to 30 kg P_2O_5 /ha had a significant influence on plant height of pearl millet.

The increased plant height with respect to the increased N: P_2O_5: K_2O levels was clearly due to the favorable effects of improved nutrient availability to the plants that ultimately contributed to better root and shoot growth. This might have enhanced the meristematic activities, internodal length and number of internodes, which enhanced the plant height, growth and development. Similar results were reported by Yadav (1998) that the plant height of pearl millet increased with N fertilizer application at the rate of 80 kg/ha under rainfed conditions. Chaudhari *et al*. (2002) also revealed that the application of 60 and 90 kg N/ha significantly enhanced the plant height over control and 30 kg N/ha, which were comparable. Sheoran *et al*. (2016) also reported that the application of 90 kg N/ha registered the highest plant height over control.

The tallest variety was Co (Cu) 9 at 30 DAS (102 cm) and also at flowering (180 cm) whereas the lower plant height was for Dhanashakthi (141 cm at flowering) and the data is given in Table 3 and figure 3. This height difference was due to the genetic characters of the varieties. Plant height is considered as the varietal character which determined the productivity of the crop in terms of straw yield. The same findings were reported by Nayak *et al*. (2020) that the plant height of varieties Dhanashakthi and ABV 04 were 144 cm and 166 cm respectively and by Divya *et al*. (2017) that it was 182 cm for Dhanashakthi. Meena *et al*. (2012) reported that the plant height of

"Rajasthan Bajra Chari-2" was significantly higher than other varieties at all growth stages of the crop.

The plants which received various N: P_2O_5: K_2O levels registered comparable values of total number of tillers with an average of 4.5 tillers per plant (Table 2). Varietal differences as well as the interaction of N: P_2O_5: K_2O levels and varieties were also found to be non-significant. Pearl millet is a low tillering crop and Meena *et al*. (2012) reported that total number of tillers per plant was 3-5 in bajra varieties.

Better growth with N: P_2O_5: K_2O application is also evident from higher Leaf Area Index as well as length and width of leaf blade. Here also the varied levels of N: P_2O_5: K_2O resulted in comparable length, width and LAI (Table 4 and figure 4). This might be due to poor nutrient use efficiency at higher doses. Statistically comparable values were recorded for all N: P_2O_5: K_2O levels applied with an average length, width and LAI of 57.86 cm, 3.11 cm and 3.87 respectively. This marked response to N: P_2O_5: K_2O application is evident from significantly lower values in absolute control with 51.02 cm length, 2.67 cm width and 2.94 LAI, which was 12, 14 and 24 per cent low respectively compared to average value. It might be due an increased availability of primary nutrients. The application of fertilizers, particularly nitrogen in earlier stages of the crop enhanced the leaf area index over control, because of the delayed leaf senescence, higher photosynthetic rate and that contributed to extended leaf area duration.

This result was in line with Tiwana *et al*. (2003) and Rehman *et al*. (2010) that there was significant increase in Leaf Area Index and leaf area duration by the application of fertilizers up to 80: 60: 30 kg/ha N: P_2O_5: K_2O respectively over control. The same was in conformity to the findings of by Ali (2015) that increased LAI at 30 and 60 DAS was due to the response to higher levels of nitrogen. Among varieties, Leaf Area Index of Co (Cu) 9 was significantly higher (4.71) followed by Co 10 (3.96). This resulted from higher leaf length as well as more number of leaves of this variety. The variety Dhanashakthi had broader leaves (3.23 cm), but leaf length was less (51.83 cm) and the leaf number was also less ultimately resulting in lower LAI of 2.7. The leaf blade length varied from 51.83 cm in Dhanashakthi to 60.82 cm in Co (Cu) 9 which

was statistically superior compared to other varieties. These differences were because of the varietal characters.

There was no significant variation in leaf - stem ratio by the application of varied N: P_2O_5: K_2O levels (Table 5). Varietal differences were observed and the highest leaf - stem ratio was registered in Dhanashakthi, which was statistically superior (0.28) than Co (Cu) 9. In Dhanashakthi, the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O and 90: 45: 45 kg/ha N: P_2O_5: K_2O resulted a superior in leaf – stem ratio, that were on par. The lowest value registered in Co (Cu) 9 with the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O. The leaf – stem ratio is an important quality parameter of bajra. Higher leaf – stem ratio indicates higher leafiness of the crop which is a desirable character to use the variety as a fodder crop. This is probably due to the reason that the growth of leaf and stem was higher in N: P_2O_5: K_2O applied treatments leading to almost constant ratios. There was an increase in leaf – stem ratio by the application of nitrogen fertilizer as reported by Gasim (2001). Similar findings were observed by Tiwana *et al*. (2003) by the application of nitrogen up to 75 kg/ha that due to the production of more number of leaves with higher leaf area. In the present study, the length and width of leaf blade was higher in fertilizer applied plots compared to control.

There was not much variation in days to 50 % flowering with respect to different levels of N: P_2O_5: K_2O fertilizers applied. On an average, 42 days were taken to reach 50 per cent flowering stage. The influence of different N: P_2O_5: K_2O levels on duration of pearl millet was found to be non-significant. This may be probably due to the short duration of the crop and genetic makeup with poor response to higher doses of nutrients. Moreover, bajra is a poor tillering crop and the duration of vegetative growth phase seems to be not affected by nutrient supply.

However, the varietal differences were significant in days to 50 % flowering and harvest (Table 6 and figure 5). The variety Co (Cu) 9 took longer duration of 47 days to reach 50 per cent flowering and 79 days to harvesting. But, Dhanashakthi was earlier in flowering and maturing with 38 days and 63 days respectively. Variations in days to 50 % flowering and days to harvest of the crop was because of the varietal characters. Rai *et al*. (2014) reported that the time to flowering of variety Dhanashakthi was in 45

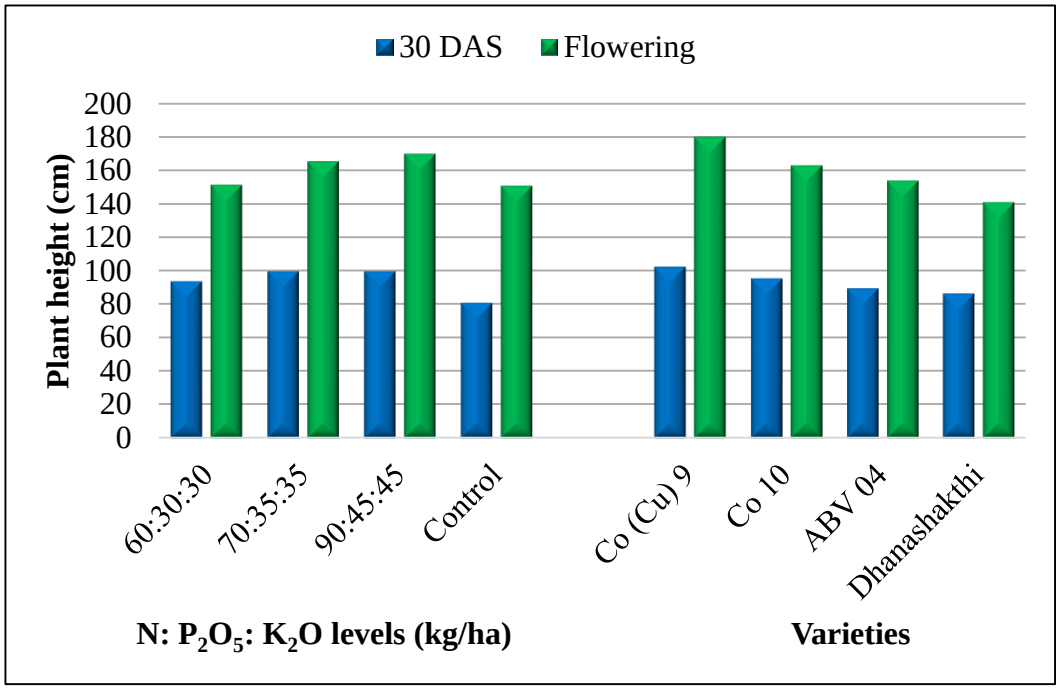


Figure 3. Plant height of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

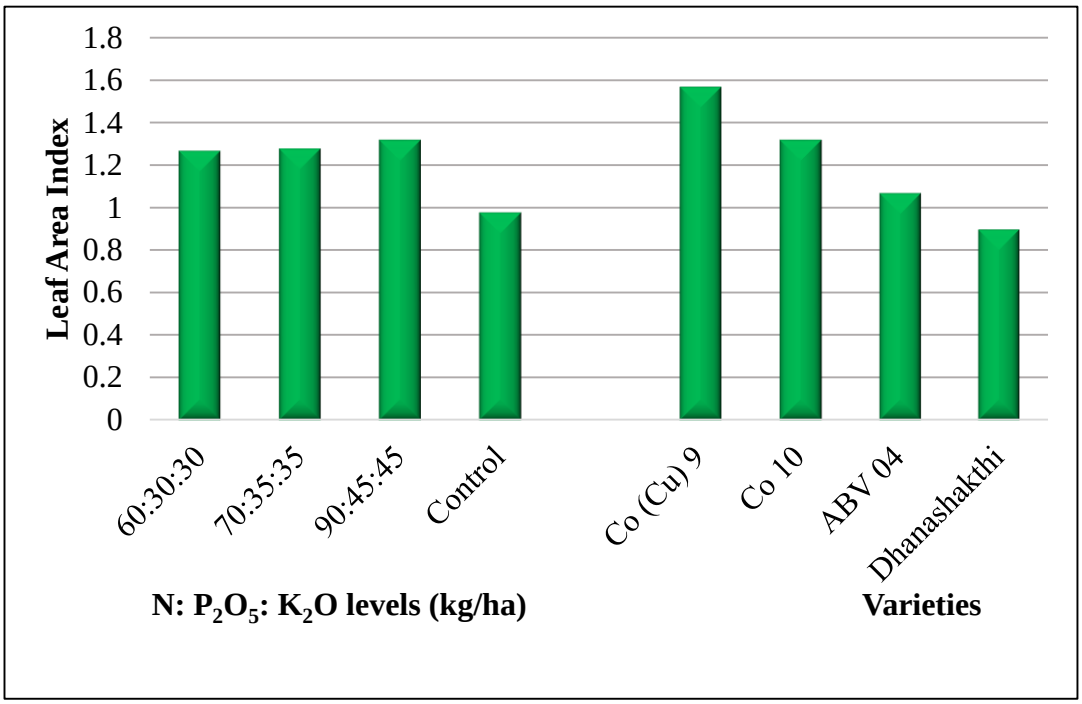


Figure 4. Leaf Area Index of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

DAS at ICRISAT, Hyderabad. Similar results have been reported by Nayak *et al*. (2020).

As the levels of N: P_2O_5: K_2O application increased, the dry matter accumulation also increased at different stages of growth with significant variation due to nutritional levels (Table 7 and figure 6). Application of 70: 35: 35 kg/ha N: P_2O_5: K_2O (778.56 kg/ha) was comparable with 90: 45: 45 kg/ha N: P_2O_5: K_2O (647.36 kg/ha) in dry matter production at 30 DAS. Plant height also showed a similar pattern. But at flowering and harvest stage, 90: 45: 45 kg/ha N: P_2O_5: K_2O application observed as superior in dry matter production. There was 32 per cent increase in dry weight compared to absolute control. Increased dry matter accumulation resulted from the availability of more nutrients to plants. It is an established fact that dry matter production can be enhanced by the application of increasing rates of primary nutrients. The increased availability resulted in more plant height, more leaf area and efficient photosynthesis that finally enhanced the dry matter accumulation. Sheoran *et al*. (2016) registered a positive correlation of maximum dry matter production with the application of nitrogen @ 60 kg N/ha and 90 kg N/ha compared to lower levels in pearl millet. Bhanuchandar *et al*. (2020) recorded maximum plant dry weight at 90 DAS by the application of N: P_2O_5: K_2O at the rate of 75: 40: 40 kg/ha and 60: 40: 20 kg/ha which were comparable statistically.

The varietal differences in dry matter production were statistically significant. Except Dhanashakthi, all other varieties registered statistically comparable dry matter production at all stages (Table 7 and figure 6). At flowering, Co (Cu) 9 was found to be better in dry matter production whereas both Co (Cu) 9 and Co 10 were comparable at harvest. The variety Dhanshakthi registered the lower dry matter at 30 DAS, flowering and harvest stage. This variety registered lower plant height and more leafiness due to its shorter duration as well as inherent genetic makeup. According to the study of Divya and Vani (2019), the dry matter production of Dhanashakthi at harvest was 7820 kg/ha. Meena *et al*. (2012) reported that the production of dry matter was more in "Rajasthan Bajra Chari-2" than other varieties at different growth stages and concluded that it was

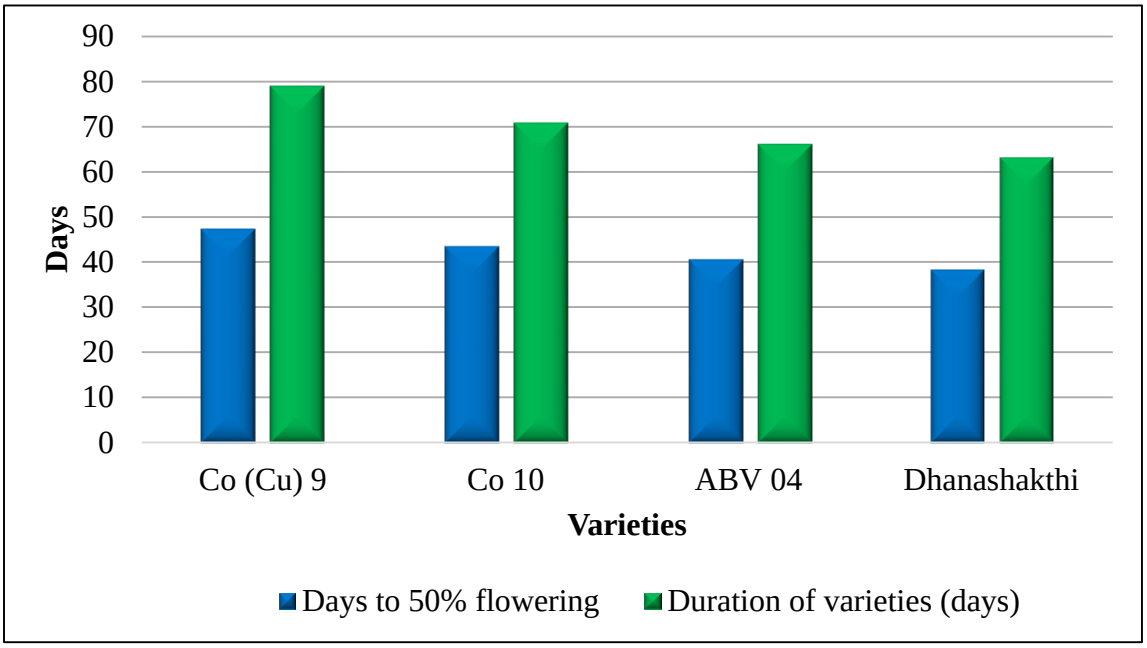


Figure 5. Days to 50 % flowering and harvest of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

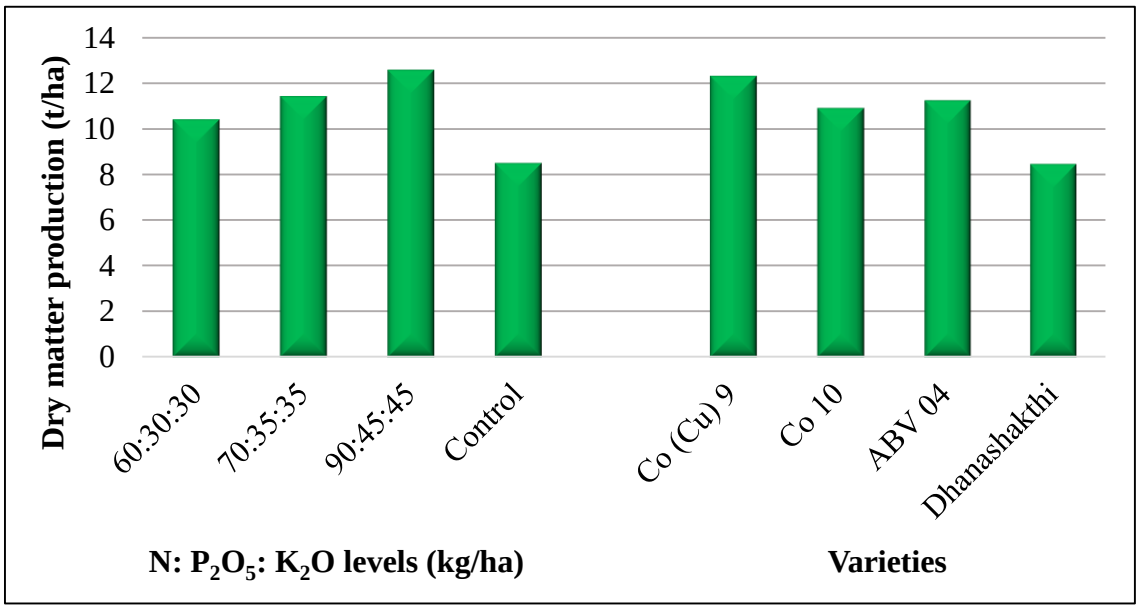


Figure 6. Dry matter production of pearl millet varieties at harvest as influenced by N: P_2O_5: K_2O levels

due to the genetic characters of the variety. Shekara *et al*. (2020) also reported wide variations in dry matter accumulation in pearl millet varieties.

5.2 Yield attributes of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

Earhead length was not influenced by the application of different N: P_2O_5: K_2O fertilizers. The average length of earhead was 22.60 cm. It was against the finding of Rajput (2006) and (Gautam *et al*., 2020) who noticed the increased response in terms of earhead length of pearl millet to the increasing levels of N: P_2O_5: K_2O fertilizers. However in case of varieties, significant variation was observed (Table 8 and figure 7). The longest earhead (26.62 cm) was observed in variety Co (Cu) 9 which was 27 per cent higher compared to Dhanashakthi. Co 10 (22.91 cm) and ABV 04 (21.47 cm) were at par. The shortest earhead was in Dhanashakthi (19.44 cm). Nayak *et al*. (2020) observed panicle length of varieties Dhanashakthi and ABV 04 which were 17.9 cm and 18.1 cm respectively. This is because of the varietal characters.

The application of N: P_2O_5: K_2O levels had a significant influence on weight of grains per earhead. The plants which got 90: 45: 45 kg/ha N: P_2O_5: K_2O gave the highest value of grain weight per earhead (36.93 g), which was superior to others. The other two N: P_2O_5: K_2O levels as well as absolute control had comparable weight of grains with an average of 31.47 g per earhead which resulted in 15 per cent decrease over the highest level. This might be due to the significant effects of potassium fertilizers applied to plants which enhanced the number of grains per earhead, nutrient uptake and photosynthetic activity (Yadav *et al.*, 2011). Among varieties, Co 10, ABV 04 and Dhanashakthi were at par with an average of 34.02 g (Table 8 and figure 7). The lowest weight of grains was in the variety Co (Cu) 9 (29.27 g) which can be attributed to the varietal character.

As the N: P_2O_5: K_2O levels increased, test weight showed an increasing trend. Application of 90: 45: 45 kg/ha N: P_2O_5: K_2O and 70: 35: 35 kg/ha N: P_2O_5: K_2O resulted a comparable test weight of 12.89 g and 11.80 g respectively. The level of 60: 30: 30 kg/ha N: P_2O_5: K_2O (10.33 g) and absolute control (9.71 g) were at par. The increased nitrogen levels enhanced better grain filling by giving bolder sized grains and

that might be the reason for the increased 1000 grain weight. Chaudhari *et al*. (2018) reported that the higher dose of nitrogen fertilizers provided the higher test weight of grains. This was in line with the results of Rajput (2006), who found significant increase in thousand grain weight in bajra by the application of N: P_2O_5: K_2O fertilizers, due to better grain tillering.

Among varieties, 1000 grain weight ranged from 7.99 g in Co (Cu) 9 to 13.35 g in Dhanashakthi (Table 8 and figure 8). The variety Dhanashakthi and ABV 04 were superior to other two varieties since it had bolder sized grains. The least test weight was registered in Co (Cu) 9 which was 40 per cent low compared to test weight of Dhanashakthi. The genetic makeup of these varieties directly related to the test weight of grains. Nayak *et al*. (2020) observed that the test weight of varieties Dhanashakthi and ABV 04 were 15.2 g and 11.4 g respectively. But, in the study of Pawase *et al*. (2021), 1000 grain weight of variety Dhanashakthi was 9.32 ±0.30 g. This results also substantiate the finding of Divya *et al*. (2017) who noticed the higher test weight in hybrid PHB-3 due to the increased accumulation of assimilates in grains and that ultimately led to the production of bold sized grains.

5.3 Grain and straw yield of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

The addition of primary nutrients considerably enhanced the grain yield compared to no application. Superior grain yield of 3360 kg/ha resulted by the addition of N: P_2O_5: K_2O level of 90: 45: 45 kg/ha (Table 9 and figure 8). Application of 70: 35: 35 and 60: 30: 30 kg/ha N: P_2O_5: K_2O yielded the next best grain yield (3,107 kg/ha and 2,700 kg/ha respectively), whereas lowest yield of 2,323 kg/ha was recorded in absolute control. However, the yield at higher dose of 90: 45: 45 kg/ha N: P_2O_5: K_2O was also 7.5 per cent higher compared to 70: 35: 35 kg/ha N: P_2O_5: K_2O. This marginal increase indicate that the fertilizer use efficiency is less above 70: 35: 35 kg/ha N: P_2O_5: K_2O as the nutrient demand was met at lower dose. Also the soil had high phosphorus and medium nitrogen and potassium status. A marked increase in grain yield of pearl millet indicate that the high yielding varieties should be fertilized adequately to get better productivity. The increased grain yield at these two levels was mainly due to the

cumulative effect of increasing trend observed in major yield attributing characters *viz*. weight of grains per earhead and test weight. This is confirmed by Ghosh *et al*. (2009) that the beneficial effect of nutrients on yield attributes might be attributed to the influence of N, P and K nutrition on growth parameters resulting in increased nutrient uptake, high nutrient use efficiency and higher dry matter production as a results of efficient assimilation of photosynthates. Bhuva *et al*. (2018) reported that the application of 100: 45 N: P_2O_5 kg/ha to pearl millet registered the highest crop yield and returns under rainfed condition of Gujarat. Increased grain yield due to application of fertilizers have also been reported by many researchers.

Three varieties ABV 04, Co 10 and Dhanashakthi were comparable with respect to grain yield with an average of 3096 kg/ha and were superior to variety Co (Cu) 9 (Table 7 and figure 8). Comparable weight of grains per earhead and test weight were observed for these varieties in this study. There would be better partitioning of assimilates in variety Dhanashakthi. Nayak *et al*. (2020) observed that the grain yield of varieties Dhanashakthi and ABV 04 were 1137 and 1850 kg/ha under rainfed condition of Odisha. The higher grain yield was registered in hybrid PHB-3 (3239 kg/ha) compared to ICMV-221(2389 kg/ha) and Dhanashakti (2605 kg/ha) by Divya *et al*. (2017).

Significant difference in straw yield could be observed with application of N: P_2O_5: K_2O fertilizers (Table 9 and figure 8). The straw yield was 10,753 kg/ha in 70: 35: 35 kg/ha N: P_2O_5: K_2O and that was statistically comparable to 90: 45: 45 kg/ha N: P_2O_5: K_2O (10,391 kg/ha). The comparable straw yield indicates that the dose of 90: 45: 45 kg/ha N: P_2O_5: K_2O is not the optimum requirement of the crop and 70: 35: 35 kg/ha N: P_2O_5: K_2O is enough to meet the nutrient demand. The straw yield in absolute control and 60: 30: 30 kg/ha N: P_2O_5: K_2O was 6,670 kg/ha and 8,293 kg/ha respectively, both were at par. The comparable yield shows that the crop could not express the potential yield at a fertilizer dose of 60: 30: 30 kg/ha N: P_2O_5: K_2O. Also the medium nutrient status of nitrogen and potassium and high phosphorus in soil helped to meet the crop requirement to some extent. The increased straw yield is the cumulative effect of the enhanced biometric parameters *viz*. plant height (170 cm), total number of tillers (5), leaf area index (1.32) and dry matter production (12.555 kg/ha) were

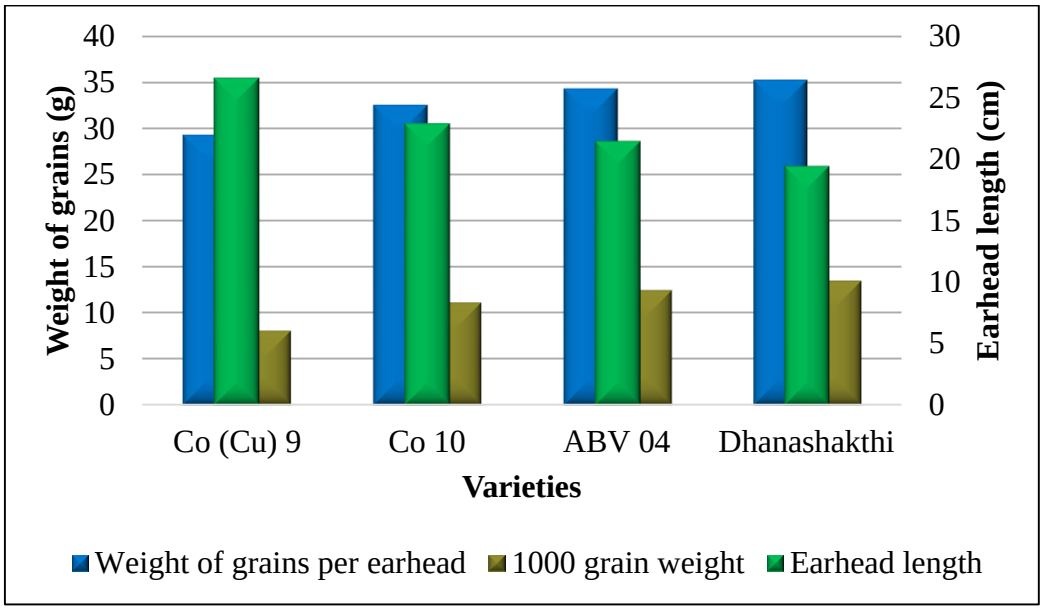


Figure 7. Test weight, weight of grains and earhead length of pearl millet varieties

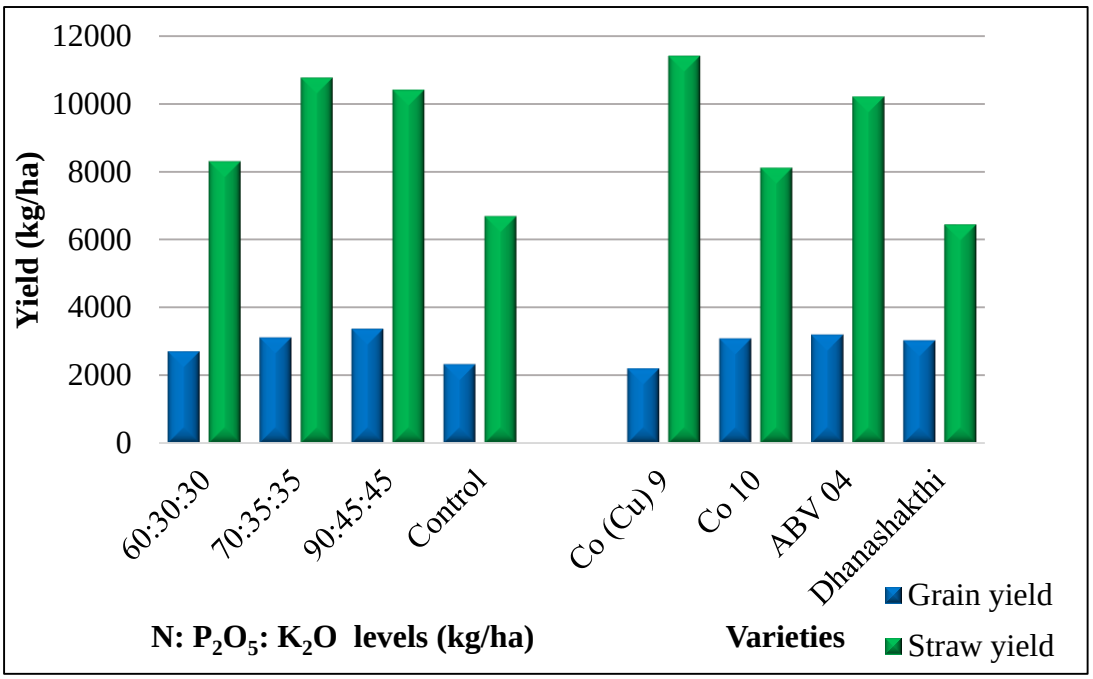


Figure 8. Grain and straw yield of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

increased in plants which received more N: P_2O_5: K_2O levels of 90: 45: 45 kg/ha. The addition of nitrogen enhances the cell division as well as the cell elongation by the activity of cytokinins. Besides, it is a component of porphyrins of chloroplast that improves the growth and yield parameters of crop due to increased photosynthesis. This is in concurrence with the results of the study by Ayub *et al*. (2007) where an increase in straw yield with the application of nitrogen at 100 kg/ha over lower doses was registered. Similar findings were reported by Sheoran *et al*. (2016) and Bhanuchandar *et al*. (2020) with the application of 90: 40: 40 kg/ha N: P_2O_5: K_2O and 75: 40: 40 kg/ha N: P_2O_5: K_2O respectively. Gautam *et al*. (2020) noticed the significant effect of phosphorus application up to 30 kg P_2O_5/ha in straw yield and it is attributed to improved nutrient availability, greater uptake and high photosynthesis.

Comparable and higher straw yield was registered in varieties Co (Cu) 9 (11,390 kg/ha) and ABV 04 (Table 9 and figure 8). The lowest straw yield of 6,430 kg/ha was noticed in variety Dhanashakthi and comparable to Co 10 (8,096 kg/ha). Rai *et al*. (2014) found that the straw yield of variety Dhanashakthi was 5.30 t/ha whereas, Divya *et al*. (2017) reported 4.9 t/ha of straw yield for this variety. Dhanashakthi was a dwarf variety compared to other three varieties and registered the lowest plant height at both 30 DAS and flowering stage. The earhead length was also the lowest and this variety had higher leaf – stem ratio. It can because that the straw yield of Co (Cu) 9 was almost double compared to Dhanashakthi. Plant height and dry matter production was also considerably higher for this variety.

The addition of different levels of N: P_2O_5: K_2O did not affect the harvest index in bajra. The average HI was 0.29. This is due to the fact that both grain yield and straw yield increased due to nutrient application. Contradictory to this, Chaudhary *et al*. (2018) found that there was an increase in Harvest Index by the effective utilization of nitrogen fertilizers. Dhanashakthi recorded highest and superior HI of 0.34 (Table 9). This is because of the lower straw and higher grain yield registered in variety Dhanashakthi. The same finding had been reported by Divya *et al*. (2017) that Harvest Index of variety Dhanashakthi was 0.35. The next best were Co 10 and ABV 04 with a mean value of 0.27, and both were on par. The difference in HI between the varieties

could be attributed to the difference in assimilate partitioning efficiency, grain yield and straw yield.

5.4 Quality parameters of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

The addition of N: P_2O_5: K_2O levels to the varieties had a significant effect in crude protein per cent compared to absolute control. Among nutrient levels, the greatest N: P_2O_5: K_2O level of 90: 45: 45 kg/ha resulted in the highest crude protein content in grain of 13.03 per cent, which was superior to the other levels (Table 10). It had 23 per cent increase over absolute control. Other N: P_2O_5: K_2O levels as well as absolute control registered statistically comparable values of crude protein. The range was 10 to 11.39 %. Nitrogen is the major component of proteins. So, the increased crude protein content in grain was observed due to the increased nitrogen levels in grain with more uptake. The relative contribution of more number of leaves to total dry matter production with higher concentration of proteins in dry matter due to the application of increased nitrogen might be another reason for higher protein content. Similar results were reported by Kumari *et al*. (2017) that there was 13 per cent increase in protein content of grain by the supplementation of NPK at 100: 45: 45 kg/ha. Also, Golada *et al.* (2012) reported that the addition of nitrogen up to 100 kg/ha significantly improved the crude protein content of pearl millet grain. The increase in crude protein contents with the application of nitrogen fertilizer has also been reported by Parihar *et al*. (2005) and Ayub *et al*. (2007).

The average value of crude protein was 11.37 % among varieties and the varietal differences were non-significant. Bajra being a cereal crop, the range of crude protein content is narrow. However, varietal differences in protein content is reported in some studies. The crude protein content of variety Dhanashakthi was 11.65 (± 0.09) per cent according to the study of Kulthe *et al*. (2016), which is a biofortified variety released from ICRISAT with Fe content of 81 ppm.

Crude fiber content of bajra grain did not vary much with the application of different N: P_2O_5: K_2O fertilizers (Table 10), though, the content was slightly lower in

grains from the plot where no fertilizer was applied. However, Ayub *et al*. (2007) and Safdar (1997) reported that crude fiber content was enhanced with the addition of nitrogen up to the rate of 100 kg/ha. Among varieties, the lowest crude fiber content was recorded in grains of variety Co 10 (1.82 %). Other varieties had crude fiber content of 2.19 – 2.43 %. Varietal differences in crude fiber content of grain is reported by Kulthe *et al.* (2016) who found that the variety Dhanashakthi had highest crude fiber of 2.63 (± 0.02) per cent over other two varieties Shanti and Pioneer 86M64.

5.5 Nutrient uptake of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

The increased accessibility of nutrients and their higher uptake by plants might have accelerated the rate of important physiological processes in plant which resulted in increased growth and yield attributes. The application of different N: P_2O_5: K_2O levels had a significant influence on nutrient uptake at harvest (Table 13 and figure 9). The highest and superior nitrogen uptake was recorded in the plants that received 90: 45: 45 kg/ha N: P_2O_5: K_2O (437 kg/ha) with 51 per cent increase compared to absolute control. This increase in nitrogen dose and split application might have increased the supply of nitrogen to the plants. Other two N: P_2O_5: K_2O levels were found to be comparable with an average N uptake of 330 kg/ha. Latha and Singh (2003) observed the same result that there was an increase in nitrogen uptake by straw and grain with the application of increased levels of fertilizers.

P uptake was the highest with the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O (126 kg/ha) and that was on par to other two N: P_2O_5: K_2O levels. Gautam *et al*. (2020) attributed the increased phosphorus uptake by grain and straw to the combined effect of both nitrogen and phosphorus application. K uptake was also comparable at different N: P_2O_5: K_2O levels with an average of 358 kg/ha. The increased K uptake also might be due to the accumulation of more dry matter in the form of shoot and root development. Increase in K uptake by the application of fertilizers at 80 kg N/ha and 30 kg P_2O_5/ha had been reported by Gautam *et al*. (2020). Similarly, Yadav *et al.* (2011) noticed the improvement in potassium content and uptake by the application of nitrogen and potassium to the plants. In absolute control, the uptake of primary nutrients was very less compared to other treatments (215 kg/ha of N, 48 kg/ha of P and 267 kg/ha of

K). These results were confirmed by Singh *et al*. (2006), who recorded that the addition of increasing levels of nitrogen and phosphorus enhanced the uptake of N, P and K in both grain and straw of pearl millet.

Among varieties, there was only a slight difference with respect to nitrogen uptake (Table 13). The N uptake of variety Co (Cu) 9 (382 kg/ha) was comparable with ABV 04 (339 kg/ha) and Co 10 (322 kg/ha). The lowest uptake was in Dhanashakthi (268 kg/ha), however it was found to be on par with Co 10 due to less straw yield. The varieties Co (Cu) 9, ABV 04 and Dhanashakthi were on par in phosphorus uptake followed by Co 10 (79 kg/ha). There was comparable potassium uptake in ABV 04, Co (Cu) 9 and Co 10 with 356 kg/ha on an average. Whereas, Dhanashakthi had lesser K uptake of 273 kg/ha due to the lower dry matter accumulation. According to Binjola and Kumar (2013), the nutrient uptake of the varieties depended on the genetic features of plants related to dry matter production and nutrient absorption.

5.6 Soil status as influenced by N: P_2O_5: K_2O levels on pearl millet varieties

The pH and EC of soil did not vary significantly with respect to the N: P_2O_5: K_2O levels and varieties of bajra. There was an increase in organic carbon content from 0.72 % to 1.11 % with respect to different N: P_2O_5: K_2O levels (Table 11), this could be due to the application of farm yard manure uniformly to all treatments. The application of 90: 45: 45 kg/ha and 70: 35: 35 kg/ha N: P_2O_5: K_2O levels to the soil registered comparable values. The available nitrogen and potassium content of the soil was found to be non-significant with respect to different N: P_2O_5: K_2O levels, varieties and their interaction. Whereas, a significant change in available phosphorus was noticed with respect to different N: P_2O_5: K_2O levels (Table 12). Phosphorus status was enhanced by the application of phosphorus fertilizers. The available P obtained by the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O (107 kg/ha) was on par with 70: 35: 35 kg/ha N: P_2O_5: K_2O (95 kg/ha) and 60: 30: 30 kg/ha N: P_2O_5: K_2O (79 kg/ha). This might be due to the difference in rate of mineralization of fertilizers and leaching losses of applied fertilizers.

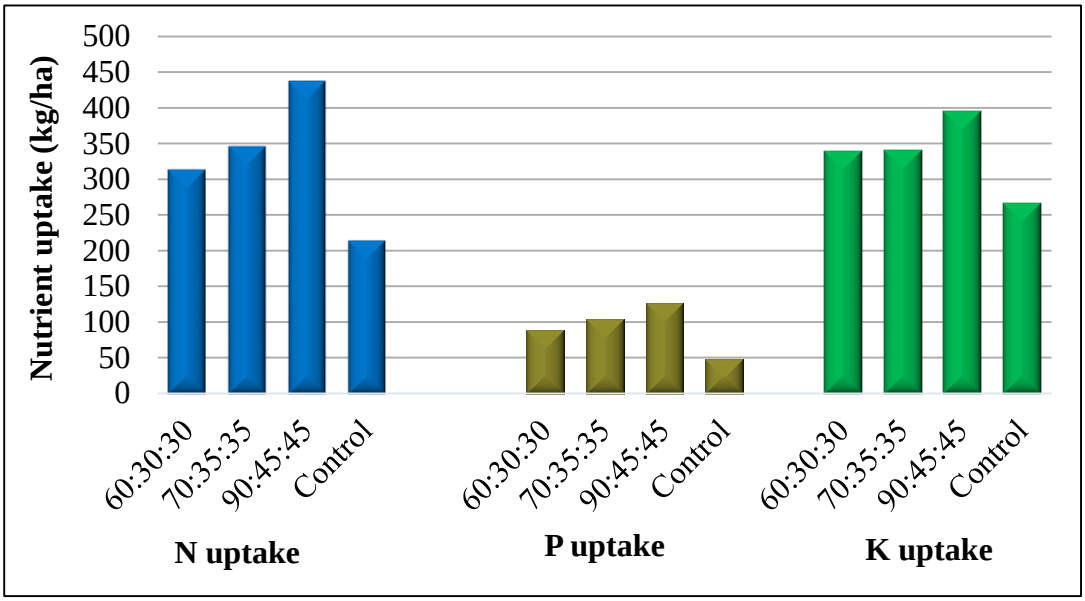


Figure 9. Nutrient uptake at harvest of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

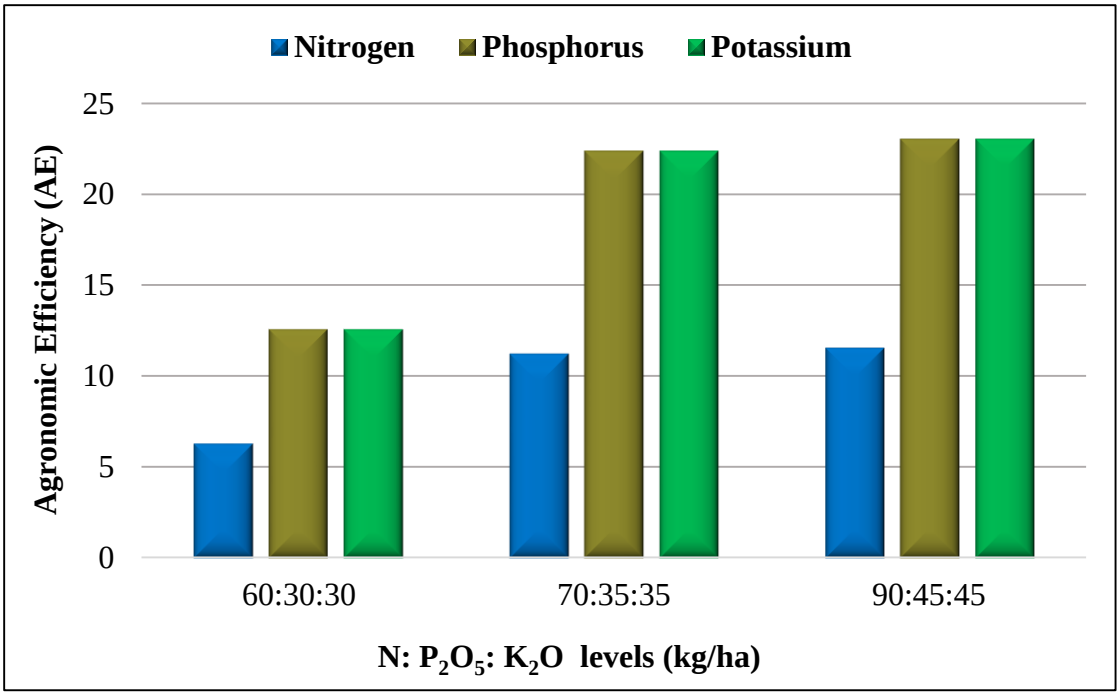


Figure 10. Agronomic efficiency of pearl millet as influenced by N: P_2O_5: K_2O levels

5.7 Cost benefit analysis of pearl millet varieties as influenced by N: P_2O_5: K_2O levels

The cost of cultivation of pearl millet was Rs. 60500 /ha without any fertilizer application and the fertilizer application alone increased the cost by Rs. 6,250 /ha in the lowest dose of 60: 30: 30 kg/ha N: P_2O_5: K_2O to Rs. 15,900 /ha in the highest dose of 90: 45: 45 kg/ha N: P_2O_5: K_2O (Table 14).

There was considerable increase in return by nutrient application and hence for getting maximum return fertilizer application is a must. The increase in gross and net returns over other fertilizer applications were 20 and 30 per cent respectively in the lowest and highest N: P_2O_5: K_2O levels. The increase in straw and grain yield resulted in higher returns. It can be seen that gross return from grain yield alone increased from Rs. 69,674 /ha in no N: P_2O_5: K_2O application to Rs. 1, 00,800 /ha in higher dose of N: P_2O_5: K_2O application. The marginal return being is Rs. 31,126 /ha and the percentage increase being 31 per cent. The corresponding value for of 60: 30: 30 kg/ha N: P_2O_5: K_2O and of 70: 35: 35 kg/ha N: P_2O_5: K_2O were Rs. 19,787 /ha and Rs. 7,578 /ha respectively. In the case of straw yield also, the increased yield by fertilizer application resulted in more returns. The absolute control registered returns of Rs. 17,083 /ha compared to the highest returns of Rs. 28,205 /ha in 70: 35: 35 kg/ha N: P_2O_5: K_2O (39 per cent increase).

The viability of cultivation can be ascertained by analyzing the net returns per ha. There was remarkable increase and almost doubled net returns by fertilizer application (Table 14 and figure 12). The higher value of Rs. 53,186 /ha along with higher B: C ratio of 1.78 was registered for N: P_2O_5: K_2O of 70: 35: 35 kg/ha. The next higher amount of Rs. 51,670 /ha with B: C ratio of 1.70 was for 90: 45: 45 kg/ha N: P_2O_5: K_2O. There was only a marginal increase of Rs. 1,516 /ha between these two N: P_2O_5: K_2O levels. This was due to the fact that the cost for nutrient application in 90: 45: 45 kg/ha N: P_2O_5: K_2O alone was Rs. 8,159 /ha compared to 70: 35: 35 kg/ha N: P_2O_5: K_2O.

A comparison of different high yielding varieties show that the variety ABV 04 is the best one in terms of total returns as well as returns from grain and straw (Table 14).

The B: C ratio was also higher (1.79) and the data is given in Table 14 and figure 11. The variety Co 10 and Dhanashakthi also were good and registered returns of Rs. 92,253 /ha and Rs. 90,771 /ha respectively through grain yield, though, straw yield was less. Hence, these three varieties can be recommended for bajra cultivation in Kerala for grain purpose. The variety Co (Cu) 9 was inferior to the other varieties in grain yield. However, the straw yield was the highest for both Co (Cu) 9 and ABV 04 and these varieties can be recommended in situations where bajra is grown for fodder purpose. Here, the additional returns through grain yield was only Rs. 7,578 /ha which was lower than the cost involved in fertilizer application. This shows that the fertilizer use efficiency was less and higher doses of fertilizer application is not economically viable for pearl millet cultivation. Hence considering the economics of cultivation, a fertilizer dose of 70: 35: 35 kg/ha N: P_2O_5: K_2O can be recommended for pearl millet cultivation in Kerala.

An assessment of Agronomic Efficiency (AE) of applied nutrients also worked out and it was found that the nutrient use efficiency could be considerably enhanced by increasing the nutrient dose from 60: 30: 30 kg/ha N: P_2O_5: K_2O to 70: 35: 35 kg/ha N: P_2O_5: K_2O (Figure 10). The Agronomic efficiency of nitrogen increased from 6 to 11 kg/kg whereas, phosphorus and potassium increased from 12.6 to 22.4 kg/kg by the application of N: P_2O_5: K_2O from 60: 30: 30 kg/ha to 70: 35: 35 kg/ha. It was seen that the efficiency at N: P_2O_5: K_2O levels of 70: 35: 35 kg/ha and 90: 45: 45 kg/ha was almost same. Hence, it can be concluded that the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O can be recommended as the fertilizer dose for pearl millet cultivation in terms of nutrient use efficiency.

The increase in returns by fertilizer application in bajra was reported by many workers. According to Rathore *et al.* (2007) there was an increase in net returns when the fertility levels increased from control to the application of 90 kg N/ha + 45 kg P_2O_5/ha. The study of Divya *et al.* (2017) conducted at Hyderabd revealed that the benefit cost ratio for variety Dhanashakthi was 2.37. Similarly, Bhanuchandar *et al*. (2020) reported that the application of fertilizers at 75: 40: 40 kg/ha N: P_2O_5: K_2O under rainfed conditions was highly productive with respect to higher gross return, net return and B: C ratio.

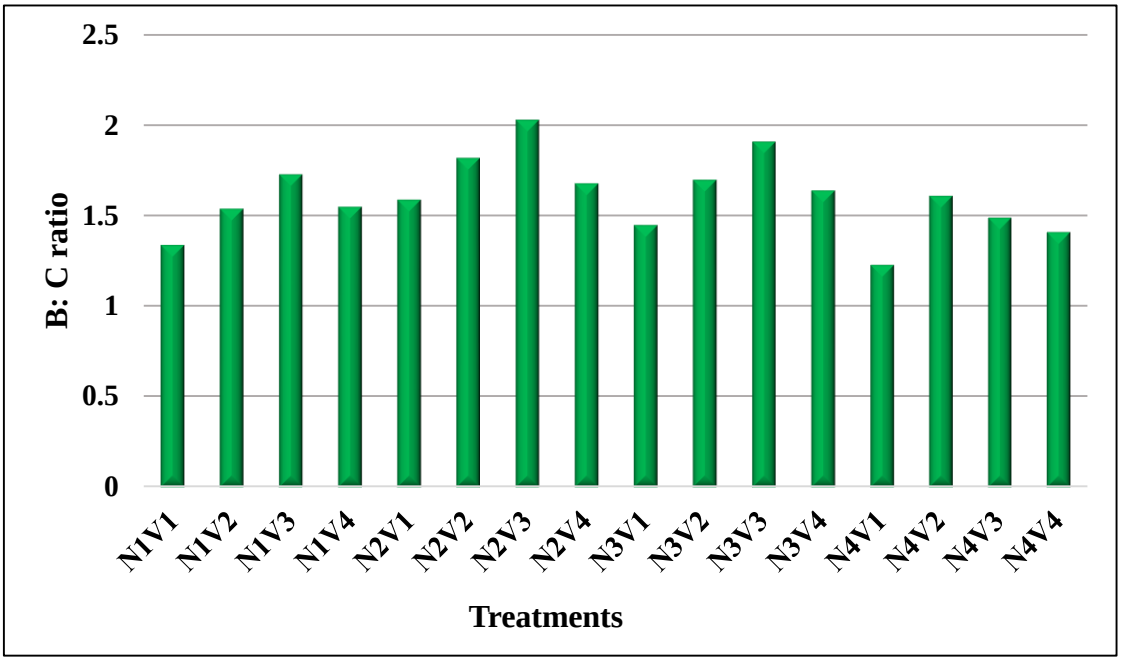


Figure 11. B: C ratio from pearl millet cultivation

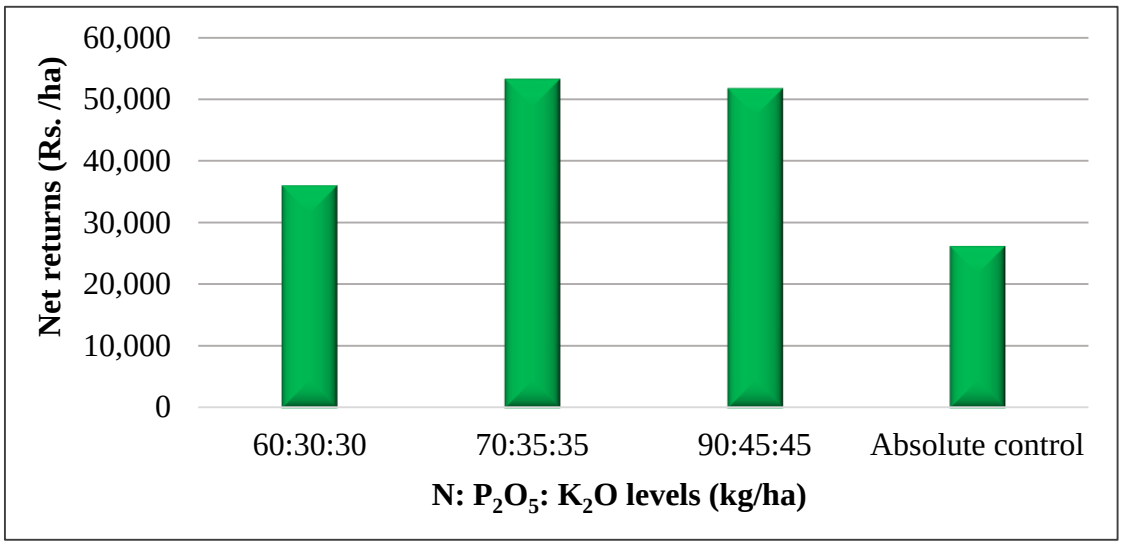


Figure 12. Net returns from pearl millet cultivation

6. Summary

6. SUMMARY

The research programme entitled "Response of high yielding varieties of pearl millet [*Pennisetum glaucum* (L.) R. Br.] to major nutrients" was conducted with the objective of assessing the performance of selected prominent high yielding varieties of pearl millet and their response to major nutrients. The varieties included in the study were Co (Cu) 9, Co 10, ABV 04 and Dhanashakthi. The experiment was conducted at Agronomy farm, Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur during the period from November, 2020 to February 2021. The area comes under AEU 10: North Central Laterites. The salient findings from the study are summarized below.

1. At 30 DAS and at flowering, the plants that received N: P_2O_5: K_2O levels of 90: 45: 45 kg/ha, 70: 35: 35 kg/ha and 60: 30: 30 kg/ha registered statistically comparable plant height. However, it was superior to absolute control where no fertilizer was applied. The plant height at 30 DAS and flowering was in the range of 80.5cm – 99 cm and 151 cm – 170 cm respectively.
2. At flowering stage, Co (Cu) 9 was the tallest variety. The variety Dhanashakthi was inferior in height compared to other varieties at all stages of observation.
3. The application of various levels of N: P_2O_5: K_2O fertilizers resulted an increase in the length (57.86 cm) and width (3.11 cm) of leaf blades compared to absolute control. The leaf blade length varied from 51.83 cm in Dhanashakthi to 60.82 cm in Co (Cu) 9, which was statistically superior compared to other varieties. Dhanashakthi had a superior leaf width of 3.23 cm.
4. There was an increase in LAI of the plants by the application of different N: P_2O_5: K_2O levels over no N: P_2O_5: K_2O application. However, different doses of N: P_2O_5: K_2O recorded comparable LAI. Co (Cu) 9 had the highest Leaf Area Index of 1.57.
5. There was no significant variation in leaf - stem ratio at active growth phase of the crop by the application of varied N: P_2O_5: K_2O levels with an average ratio of 0.24.

The highest leaf - stem ratio was registered in Dhanashakthi (0.28) and Co (Cu) 9 had lower value of 0.10.

6. In variety Dhanashakthi, the application of 70: 35: 35 kg/ha N: P_2O_5: K_2O and 90: 45: 45 kg/ha N: P_2O_5: K_2O resulted a superior in leaf – stem ratio that were at par. In case of 60: 30: 30 kg/ha N: P_2O_5: K_2O, the varieties ABV 04 and Dhanashakthi performed better and both were at par.
7. There was no variation in days to 50% flowering with respect to different levels of N: P_2O_5: K_2O fertilizers applied and the crop reached to this stage at 42 DAS. The variety Co (Cu) 9 took longer duration (47 days). Whereas, Dhanashakthi was earlier in flowering (38 days).
8. Different N: P_2O_5: K_2O levels had no influence on duration of pearl millet. However, the varieties differed significantly and Dhanashakthi reached harvest stage by 63 DAS compared to others, while Co (Cu) 9 took 79 days.
9. Fertilizer application resulted in increased dry matter production at different stages of plant growth. Application of 70: 35: 35 kg/ha N: P_2O_5: K_2O was comparable with 90: 45: 45 kg/ha N: P_2O_5: K_2O in dry matter production at 30 DAS. Varietal differences were statistically significant.
10. Dry matter production of bajra was the highest with the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O followed by other two levels. Co (Cu) 9 had the highest dry matter production followed by Co 10. At harvest stage also, statistically comparable accumulation could be observed by the application of varying N: P_2O_5: K_2O levels. The dry matter production was 12,555 kg/ha by the application of 90: 45: 45 kg/ha N: P_2O_5: K_2O which was the highest. Variety Dhanashakthi registered the lower dry matter production at all stages of observation.
11. The number of productive tillers was found to be non-significant when varied N: P_2O_5: K_2O levels were applied to pearl millet varieties. The average number of productive tillers per plant was 4.50 with respect to fertilizer levels and varieties.

12. Earhead length was not influenced by the application of different N: P_2O_5: K_2O fertilizers. In case of varieties, the longest earhead was observed in Co (Cu) 9 (26.62 cm) while the shortest was in Dhanashakthi (19.44 cm).
13. The application of different N: P_2O_5: K_2O fertilizers influenced the weight of grains per earhead. The N: P_2O_5: K_2O level of 90: 45: 45 kg/ha gave the highest value of 36.93 g, which was superior to others. Among varieties, Co 10, ABV 04 and Dhanashakthi were comparable to Co (Cu) 9 which had the lowest weight of grains per earhead.
14. Fertilizer application resulted in higher test weight also. It ranged from 7.99 g in variety Co (Cu) 9 to 13.35 g in Dhanashakthi.
15. The addition of primary nutrients resulted in enhanced grain yield of pearl millet. The grain yield at different doses of N: P_2O_5: K_2O statistically differed from each other. Superior grain yield of 3360 kg/ha resulted by the addition of N: P_2O_5: K_2O level of 90: 45: 45 kg/ha with 31 % increase over absolute control.
16. Varieties ABV 04, Co 10 and Dhanashakthi were comparable with respect to grain yield and were superior to variety Co (Cu) 9.
17. Significant difference in straw yield could be observed with N: P_2O_5: K_2O application than no fertilizer. The superior and comparable straw yield was recorded in 70: 35: 35 kg/ha N: P_2O_5: K_2O and 90: 45: 45 kg/ha N: P_2O_5: K_2O with 37 % increase over no fertilizer application.
18. Varietal differences were also significant and Co (Cu) 9 and ABV 04 were the superior varieties with respect to straw yield.
19. N: P_2O_5: K_2O levels did not affect the harvest index and average HI was 0.29. The variety Dhanashakthi recorded highest HI of 0.34 while the least was in Co (Cu) 9 with HI of 0.17.
20. The greatest N: P_2O_5: K_2O level of 90: 45: 45 kg/ha resulted in the highest crude protein content in grain (13.03 per cent). The average value of crude protein was 11.37 per cent among varieties and the varietal differences were non-significant.

21. Increase in crude fiber content of grain was observed with N: P_2O_5: K_2O application with an average content of 2.30 per cent. Crude fiber content was statistically comparable in ABV 04, Dhanashakthi and Co (Cu) 9 with an average content of 2.33 per cent and Co 10 registered a lower value of 1.82 per cent.
22. The uptake of N, P and K increased with fertilizer application with 437 kg/ha of nitrogen, 126 kg/ha of phosphorus and 358 kg/ha of potassium over 215 kg N/ha, 48 kg P_2O_5/ha and 267 kg K_2O /ha in absolute control,
23. The pH, EC of soil did not vary significantly with respect to the N: P_2O_5: K_2O levels and varieties of bajra. There was an increase in organic carbon content over no fertilizer application with respect to N: P_2O_5: K_2O levels of 90: 45: 45 and 70: 35: 35 kg/ha.
24. The available nitrogen and potassium content of the soil was found to be non-significant with respect to different N: P_2O_5: K_2O levels and varieties. Whereas, a significant change in available phosphorus was noticed with respect to different N: P_2O_5: K_2O levels.
25. Economic analysis revealed that the application of fertilizers enhanced the gross and net returns along with benefit- cost ratio in pearl millet cultivation. The highest B: C ratio and net returns from bajra cultivation were registered in N: P_2O_5: K_2O level of 70: 35: 35 kg/ha N: P_2O_5: K_2O. Three varieties ABV 04, Co 10 and Dhanashakthi can be considered for grain purpose and Co (Cu) 9 for fresh fodder since it has more vegetative growth and higher straw yield.

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Appendices

Appendix 1. Monthly weather data during the experimental period (November 2020- February 2021)

Month-year	Temperature (°C)		Mean relative humidity (%)	Wind speed (kmph)	Sunshine hours (Hrs.)	Mean monthly rainfall (mm)	Evaporation (mm)
	Maximum	Minimum					
November-2020	33	22	70	4.4	6.6	1.9	3.6
December-2020	32	21.9	65	6.7	6.3	0.2	4.4
January-2021	32.3	21.3	64	5.9	6.6	1.5	4.3
February-2021	34.6	21.6	54	5.9	9.2	0.0	5.5

Appendix 2. Cost of cultivation

Treatments	N_1V_1	N_1V_2	N_1V_3	N_1V_4	N_2V_1	N_2V_2	N_2V_3	N_2V_4	N_3V_1	N_3V_2	N_3V_3	N_3V_4	N_4V_1	N_4V_2	N_4V_3	N_4V_4
Grain yield (t/ha)	2.12	2.72	2.96	3.01	2.37	3.31	3.60	3.16	2.65	3.58	3.7	3.49	1.67	2.70	2.46	2.46
Grain returns (Rs. Lakh /ha)	0.64	0.82	0.89	0.90	0.71	0.99	1.08	0.95	0.79	1.07	1.12	1.05	0.50	0.81	0.74	0.74
Straw yield (t/ha)	8.65	7.02	8.86	4.47	12.59	8.27	10.08	6.66	10.53	7.57	11.27	6.99	8.06	5.46	5.44	3.82
Straw returns (Rs. Lakh /ha)	0.26	0.21	0.27	0.13	0.38	0.25	0.30	0.20	0.31	0.23	0.34	0.21	0.24	0.16	0.16	0.11
Total returns (Rs. Lakh /ha)	0.90	1.03	1.15	1.04	1.09	1.24	1.38	1.15	1.11	1.30	1.46	1.26	0.74	0.97	0.90	0.85
Labours cost (Rs. Lakh /ha	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Fertilizers (Rs. Lakh /ha)	0.16	0.16	0.16	0.16	0.18	0.18	0.18	0.18	0.26	0.26	0.26	0.26	0.10	0.10	0.10	0.10
Miscellaneous (Rs. Lakh /ha)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total cost (Rs. Lakh /ha)	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.76	0.76	0.76	0.76	0.61	0.61	0.61	0.61
Net returns (Rs. Lakh /ha)	0.23	0.36	0.49	0.37	0.41	0.56	0.70	0.46	0.35	0.54	0.69	0.49	0.14	0.37	0.30	0.25
B: C ratio	**1.34**	**1.54**	**1.73**	**1.55**	**1.59**	**1.82**	**2.03**	**1.68**	**1.45**	**1.70**	**1.91**	**1.64**	**1.23**	**1.61**	**1.49**	**1.41**

N_1= 60:30:30 kg/ha	V_1= Co (Cu) 9
N_2= 70:35:35 kg/ha	V_2= Co 10
N_3=90:45:45 kg/ha	V_3= ABV 04
N_4= Absolute control	V_4= Dhanashakthi

Price of grains = Rs. 40/kg	Urea= Rs.7/kg
Price of straw= Rs. 3/kg	Factomphos=Rs. 20/kg
Labour charge = Rs. 628/day	MOP= Rs. 19/kg
Cost of seed = Rs. 500/ha	Lime= Rs. 20/kg

RESPONSE OF HIGH YIELDING VARIETIES OF PEARL MILLET [*Pennisetum glaucum* (L.) R. Br.] TO MAJOR NUTRIENTS

By

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(2019-11-130)

ABSTRACT OF THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

(AGRONOMY)

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2021

ABSTRACT

Pearl millet or bajra is a major millet grown in the tropics for both food and fodder. Many high yielding varieties of pearl millet are now available for cultivation. But, the performance of these varieties and the nutrient requirement of pearl millet were not assessed in Kerala. Hence, the study entitled "Response of high yielding varieties of pearl millet [*Pennisetum glaucum* (L.) R. Br.] to major nutrients" was carried out with the objective of assessing the performance of selected prominent high yielding varieties of pearl millet and their response to major nutrients.

The experiment was carried out at Agronomy Farm, Department of Agronomy, College of Agriculture, Vellanikkara during the period from November, 2020 to February 2021. Treatments were the combinations of nutrient levels (N: P_2O_5: K_2O @ 60: 30: 30, 70: 35: 35, 90: 45: 45 kg/ha and absolute control) and four varieties released from various research institutes [Co (Cu) 9, Co 10, ABV 04 and Dhanashakthi]. The design was factorial RBD with 16 treatments and three replications.

The biometric parameters like plant height, length and width of leaf blade, Leaf Area Index and dry matter production of pearl millet were significantly influenced by the application of different N: P_2O_5: K_2O levels. The plants which got higher fertilizer doses of 90: 45: 45 and 70: 35: 35 N: P_2O_5: K_2O kg/ha had taller plants and registered higher dry matter production. The variety Co (Cu) 9 was taller with more leaf area index and dry matter production whereas, Dhanashakthi was inferior. But, it had superior leaf width and leaf-stem ratio.

The application of fertilizers had a significant influence on grain yield, yield parameters and straw yield of bajra. The highest grain weight per earhead (36.93 g) and grain yield (3360 kg/ha) were registered in plants that received 90: 45: 45 N: P_2O_5: K_2O kg/ha. The grain yield at fertilizer level of 90: 45: 45 N: P_2O_5: K_2O kg/ha showed only a marginal increase of 7.5 per cent compared to 70: 35: 35 N: P_2O_5: K_2O kg/ha (3107kg/ha). The straw yield at 90: 45: 45 and 70: 35: 35 N: P_2O_5: K_2O kg/ha were comparable (10391 and 10753 kg/ha, respectively).

The varieties ABV 04, Co 10 and Dhanashakthi had superior and comparable grain yield ranging from 3026 to 3188kg/ha and the performance of Co (Cu) 9 was inferior with 2201kg/ha. Lower straw yield was noticed in variety Dhanashakthi (6430 kg/ha) that was comparable to Co 10 (8096kg/ha). The other two varieties ABV 04 and Co (Cu) 9 registered superior straw yield of 10191 and 11390 kg/ha, respectively.

The longest earhead was for variety Co (Cu) 9 and the shortest was for variety Dhanashakthi (19.44 cm). The lowest weight of grains per earhead (29.27 g) and test weight (7.99 g) were recorded for variety Co (Cu) 9. The variety Dhanashakthi had higher test weight (13.35 g) as well as Harvest Index (0.34). The straw yield was comparable in varieties Co (Cu) 9 (11,390 kg/ha) and ABV 04 (10,191 kg/ha). The average crude protein content was 11.37 per cent and the varietal differences were non-significant. Crude fiber was comparable in ABV 04, Dhanashakthi and Co (Cu) 9 with an average content of 2.33 per cent. The crude fiber content at varied levels of primary nutrients were comparable.

The highest and superior nitrogen uptake was recorded by the application of 90: 45: 45 N: P_2O_5: K_2O kg/ha (437 kg/ha) with 51 per cent increase compared to absolute control. P uptake at 90: 45: 45 N: P_2O_5: K_2O kg/ha (126 kg/ha) was on par to that at 70:35:35 N: P_2O_5: K_2O level. But, K uptake was comparable at three N: P_2O_5: K_2O levels with an average of 358 kg/ha. Significantly lower uptake of primary nutrients were registered in absolute control.

The application of fertilizers enhanced the gross and net returns along with benefit-cost ratio in pearl millet cultivation. The highest B: C ratio (1.78) and net returns (Rs. 53,186 /ha) from bajra cultivation registered in N: P_2O_5: K_2O level of 70: 35: 35 N: P_2O_5: K_2O kg/ha, followed by the highest dose. Hence, it can be concluded that a fertilizer dose of 70: 35: 35 N: P_2O_5: K_2O kg/ha can be recommended for pearl millet cultivation in Kerala.

The varieties ABV 04, Co 10 and Dhanashakthi can be recommended for grain purpose, whereas varieties Co (Cu) 9 and ABV 04 are ideal for straw and fresh herbage. ABV 04 is a good variety with respect to both grain and straw yield.

സംഗ്രഹം

ഉഷ്ണമേഖലാ പ്രദേശങ്ങളിൽ ഭക്ഷണത്തിനും കാലിത്തീറ്റയ്ക്കും വേണ്ടി വളർത്തുന്ന ഒരു പ്രധാന ചെറു ധാന്യമാണ് പേൾ മില്ലറ്റ് അല്ലെങ്കിൽ ബജ്റ. ഉയർന്ന വിളവ് നൽകുന്ന നിരവധി ബജ്റ ഇനങ്ങൾ ഇപ്പോൾ കൃഷിക്ക് ലഭ്യമാണ്. എന്നാൽ, ഈ ബജ്റ ഇനങ്ങളുടെ വിളവും രാസവളങ്ങളുടെ ആവശ്യകതയും കേരളത്തിൽ ഇതുവരെ പഠനം നടത്തിയിട്ടില്ല. അതിനാൽ, "ഉയർന്ന വിളവ് നൽകുന്ന ബജ്റ (*പെന്നിസിറ്റം ഗ്ളോകം*) ഇനങ്ങൾക്ക് പ്രധാന പോഷകങ്ങളോടുള്ള പ്രതികരണം" എന്ന തലക്കെട്ടിലുള്ള പഠനം തിരഞ്ഞെടുത്തു.

2020 നവംബർ മുതൽ 2021 ഫെബ്രുവരി വരെയുള്ള കാലയളവിൽ അഗ്രോണമി ഡിപ്പാർട്ട്മെൻറ്റിൻറെ ഫാമിൽ പഠനം നടത്തി. വിവിധ ഗവേഷണ സ്ഥാപനങ്ങളിൽ നിന്ന് പുറത്തിറക്കിയ നാല് ഇനങ്ങൾക്ക് [Co (Cu) 9, Co 10, ABV 04, ധനശക്തി] N: P_2O_5: K_2O രാസവളങ്ങൾ നാല് തോതുകളിൽ (N: P_2O_5: K_2O @ 60: 30: 30, 70 : 35: 35, 90: 45: 45 കി.ഗ്രാം/ഹെക്ടർ) നൽകി അവയുടെ വളർച്ചയും വിളവും വിലയിരുത്തി.

ചെടിയുടെ ഉയരം, ഇലയുടെ നീളം, വീതി, ഇല വിസ്തീർണ്ണ സൂചികയും (LAI), ഡ്രൈ മാറ്റർ ഉത്പാദനം തുടങ്ങിയ ബയോമെട്രിക് പാരാമീറ്ററുകൾ വ്യത്യസ്ത N: P_2O_5: K_2O തലങ്ങളുടെ പ്രയോഗത്താൽ ഗണ്യമായി സ്വാധീനിക്കപ്പെട്ടു. ഉയർന്ന വളം ലഭിച്ച ചെടികൾക്ക് (90: 45: 45, 70: 35: 35 കിലോഗ്രാം/ഹെക്ടർ N: P_2O_5: K_2O) ഉയരം കൂടിയ ചെടികളും ഉയർന്ന ഡ്രൈ മാറ്റർ ഉൽപാദനവും രേഖപ്പെടുത്തി. Co (Cu) 9 എന്ന ഇനം കൂടുതൽ ഇല വിസ്തീർണ്ണ സൂചികയും ഡ്രൈ മാറ്റർ ഉൽപാദനവും കൊണ്ട് ഉയർന്നതാണ്. അതേസമയം ധനശക്തിക്ക് ഉയർന്ന ഇല വീതിയും ഇല - തണ്ട് അനുപാതവും ഉണ്ടായിരുന്നു.

ധാന്യവിളവ്, വൈക്കോൽ വിളവ്, മറ്റു വിളവ് പരാമീറ്ററുകൾ എന്നിവയിൽ രാസവളങ്ങളുടെ പ്രയോഗം കാര്യമായ സ്വാധീനം ചെലുത്തി. 90: 45: 45 N: P_2O_5: K_2O കി.ഗ്രാം/ഹെക്ടറിന് ലഭിച്ച ചെടികളിലാണ് ധാന്യത്തിന്റെ വിളവ് കൂടുതൽ (3360 കി.ഗ്രാം/ഹെക്ടർ) രേഖപ്പെടുത്തിയിരിക്കുന്നത്. 90: 45:

45 കി. ഗ്രാം/ഹെക്ടർ N: P_2O_5: K_2O ലഭിച്ച ചെടികളിൽ ധാന്യത്തിന്റെ വിളവ് 70: 35: 35 കി.ഗ്രാം/ഹെക്ടർ N: P_2O_5: K_2O കിട്ടിയ ചെടികളെ (3107 kg/ha) നെ അപേക്ഷിച്ച് 7.5 ശതമാനം നേരിയ വർധന മാത്രമാണ് കാണിച്ചത്. വൈക്കോൽ വിളവ് 90: 45: 45, 70: 35: 35 കി.ഗ്രാം/ഹെക്ടർ N: P_2O_5: K_2O ലഭിച്ച ചെടികളിൽ താരതമ്യപ്പെടുത്താവുന്നതാണ്. ABV 04, Co 10, ധനശക്തി എന്നീ ഇനങ്ങൾക്ക് ഹെക്ടറിന് 3026 മുതൽ 3188 കിലോഗ്രാം വരെ ഉയർന്നതും താരതമ്യപ്പെടുത്താവുന്നതുമായ ധാന്യ വിളവ് ഉണ്ടായിരുന്നു. ഇനങ്ങളായ ABV 04, Co (Cu) 9 എന്നിവ യഥാക്രമം 10191, 11390 കിലോഗ്രാം/ ഹെക്ടർ ഉയർന്ന വൈക്കോൽ വിളവ് രജിസ്റ്റർ ചെയ്തു.

ഏറ്റവും നീളമേറിയ കതിരുകൾ Co (Cu) 9 ലും ചെറിയ കതിരുകൾ ധനശക്തിയിലും രേഖപ്പെടുത്തി. മണികളുടെ ഭാരം ഏറ്റവും കുറവ് (7.99 ഗ്രാം) Co (Cu) 9 ഇനത്തിലാണ്. എന്നാൽ, ധനശക്തി ഇനത്തിന് ഉയർന്ന ടെസ്റ്റ് ഭാരവും (13.35 ഗ്രാം), വിളവെടുപ്പ് സൂചികയും (0.34) ഉണ്ടായിരുന്നു. വൈക്കോൽ വിളവ് Co (Cu) 9, ABV 04 എന്നീ ഇനങ്ങളിൽ കൂടുതലായിരുന്നു.

രാസവളങ്ങളുടെ പ്രയോഗം മൊത്ത വരുമാനവും ബജ്റ കൃഷിയിലെ B: C അനുപാതം വർദ്ധിപ്പിക്കുകയും ചെയ്തു. ഉയർന്ന B: C അനുപാതം 70: 35: 35 കി.ഗ്രാം/ഹെക്ടർ N: P_2O_5: K_2O ലഭിച്ച ചെടികളിൽ നൽകി. അതിനാൽ, കേരളത്തിലെ ബജ്റ കൃഷിക്ക് 70: 35: 35 കി.ഗ്രാം/ഹെക്ടർ N: P_2O_5: K_2O എന്ന രാസവള തോത് ശുപാർശ ചെയ്യാം.

ABV 04, Co 10, ധനശക്തി എന്നീ ബജ്റ ഇനങ്ങൾ ധാന്യ ആവശ്യങ്ങൾക്ക് ശുപാർശ ചെയ്യാവുന്നതാണ്, അതേസമയം പച്ചപ്പുല്ലിനും വൈക്കോൽ ആവശ്യങ്ങൾക്കും കൂടുതൽ അനുയോജ്യമായത് Co (Cu) 9, ABV 04 എന്നീ ഇനങ്ങളാണ്. ധാന്യത്തിന്റെയും വൈക്കോൽ വിളവിന്റെയും കാര്യത്തിൽ ഒരു നല്ല ഇനമാണ് ABV 04.