EFFICACY OF VERMICOMPOST, VERMIWASH AND AMF ON QUALITY SEED PRODUCTION OF BHINDI

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DECLARATION

I hereby declare that this thesis entitled "**Efficacy of Vermicompost, vermiwash and AMF on quality seed production of bhindi**" 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, associateship, fellowship or other similar title, of any other university or society.

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LIST OF ABBREVIATIONS

%	-	Per cent
°C	-	Degree Celsius
@	-	At the rate of
AMF	-	Arbuscular mycorrhizal fungi
ANOVA	-	Analysis of variance
BCR	-	Benefit-cost ratio
C	-	Carbon
CD	-	Critical difference
Cd	-	Cadmium
cm	-	Centimetre
cm^2	-	Square centimetre
cm^3	-	Cubic metre
Cr	-	Chromium
Cu	-	Copper
DAS	-	Days after sowing
DAT	-	Days after transplanting
DMP	-	Dry matter production
eg.	-	Example
et al.	-	And others
Fe	-	Iron
Fig.	-	Figure
$fruit^{-1}$	-	Per fruit
FYM	-	Farmyard manure
g	-	Gram
ha	-	Hectare
HI	-	Harvest index
IAA	-	Indole Acetic Acid
IBA	-	Indole Butyric Acid
K	-	Potassium
K_2O	-	Potash
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare

LIST OF ABBREVIATIONS CONTINUED

LAI	-	Leaf area index
$litre^{-1}$	-	Per litre
m	-	Metre
m^{-2}	-	Per square metre
mg	-	Milligram
Mg	-	Magnesium
ml	-	Millilitre
mm	-	Millimetre
MOP	-	Muriate of potash
N	-	Nitrogen
Ni	-	Nickel
NS	-	Non significant
P	-	Phosphorus
P_20_5	-	Phosphate
Pb	-	Lead
$plant^{-1}$	-	Per plant
$plot^{-1}$	-	Per plot
POP	-	Package of Practices
ppm	-	Parts per million
RH	-	Relative humidity
Rs	-	Rupees
S	-	Sulphur
t	-	tonnes
t ha^{-1}	-	Tonnes per hectare
VAM	-	Vesicular arbuscular mycorrhiza
$Vine^{-1}$	-	Per vine
viz.	-	Namely
Zn	-	Zinc
$ZnS0_4$	-	Zinc sulphate

Introduction

1. INTRODUCTION

Vegetables are so common in human diet that a meal without vegetable is supposed to be incomplete in any part of the world. Vegetables play an important role in human nutrition by providing carbohydrates, proteins, minerals and vitamins. India is the second largest producer of vegetables in world next to China with the production of 96.54 million tonnes from an area of 6.89 million hectare (Gopalakrishnan, 2004), India is the largest producer of bhindi contributing a production of 35.5 lakh tonnes. The total area under vegetables in Kerala is 1.81 lakh ha and bhindi occupies an area of 871 ha (FIB, 2005).

The availability of superior quality seeds of improved varieties / hybrids at optimum cropping season is single most important input for increasing productivity of vegetable crops. Presently, total seed requirement of vegetables is 70,000 tonnes (Rai, 2003) and it is estimated that 500 tonnes of hybrid seeds of bhindi are sold annually. But the quality of this seeds should be assured since quality seeds offer enormous scope to realize production targets as well as increase export earnings significantly. Crops raised from poor quality seeds are not healthy and thus rendered uneconomical. The non-availability of quality seeds is the major constraint in vegetable cultivation in India.

Recent findings in seed technology research have indicated that mother plant nutrition is one of the most important factors in the production of quality seeds. The importance of organic manure as the source of nutrition came under shadow during the last few decades on account of the rapid increase in the use of chemical fertilizers. But now, due to the high cost of fertilizers and the need to maintain soil productivity and ecological stability, have led to fresh appraisal of their role and scope in vegetable production. Vermicompost is one such potential organic manure which contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites particularly giberellins, cytokinins, auxins and group B vitamins, which can be applied alone or in combination with organic and inorganic fertilizers so for as to get better yield and quality of diverse crops (Gavrilov, 1962; Tomati *et al.*, 1983 and Bano *et al.*, 1987). Normally vermicompost contain a high percentage of humus. Humus helps soil particles form into clusters, which creates channels for passage of air and improves the capacity to hold water. Thus it adds structure to the soil and helps to retain water in the soil. The vermicompost made from different sources have different nutrient contents and the quality can be further improved by using biowastes rich in nutrients. The nutrients which have locked up in this biowastes were mobilized in to plant available forms in the casts during the passage of plant material through the gut of the worms.

Vermiwash, a liquid organic manure is an aqueous extract of a column of freshly formed vermicompost and surface washings of earthworms. Vermiwash contains macronutrients like nitrogen, phosphorus and potassium and other nutrients like calcium, magnesium, iron, manganese, zinc and copper, most of them being in plant available form. Venkateswara *et al.* (2005) reported that vermiwash contain growth promoting substances like indole acetic acid and indole butyric acid, thus improving the growth, yield, quality and resistance to pest and diseases in bhindi. They also reported that it improved the soil health by conserving natural flora and fauna of soil.

Biofertilizers are likely to assume greater significance as a supplement to inorganic fertilizers, because of high nutrient turn over, exorbitant cost of fertilizers and soil and environmental protection. AMF is one such biofertilizer which have proved to be a promising bio inoculant responsive in vegetable crops. AMF have been known to increase plant growth through mobilization of phosphorus, zinc, copper, sulphur and water through soil exploration of the hyphae. Thus it gives resistance to water stress and plant pathogens especially root diseases, enhanced tolerance to heavy metal pollution, soil salinity and increased soil aggregation by external hyphal network.

In the present decade of sustainable agriculture, the integrated plant nutrient system, in which organic manures are coupled with chemical fertilizers is of prime importance to achieve best results at low cost. This is highly relevant in seed production also.

Hence the present investigation was proposed,

i) To study the effect of different sources of organic manure and vermiwash, with and without AMF on quality seed production in bhindi

ii) To work out the economics of seed production.

Review of Literature

2. REVIEW OF LITERATURE

Vegetables are essential for a balanced diet and maintenance of good health. But in India, vegetable husbandry is not yet properly developed and we must increase the vegetable production to meet the growing demand. For this, good quality seeds of vegetables are essential. The present study is aimed at estimating the potential of using different sources of organic manure, vermiwash and AMF on quality seed production of bhindi. The efficacy of organic sources of nutrients and AMF on vegetable crops has been studied by several workers but the work regarding their influence on bhindi is meagre. So the available literature on this aspect pertaining to crops other than bhindi is also reviewed hereunder.

2.1 EFFECT OF DIFFERENT SOURCES OF ORGANIC MANURE ON GROWTH CHARACTERS OF CROPS

2.1.1 Effect of Vermicompost on Growth Characters of Bhindi

Vermicompost is a potential organic manure containing nitrogen fixing, phosphorus solubilising and cellulose decomposing organisms (Bhawalker, 1992). In an experiment conducted at the Regional Agricultural Research Station, Pilicode, Govindan *et al.* (1995) reported that in okra vermicompost application, as a substitute for FYM along with fertilizer application as per POP recommendation of Kerala, enhanced the growth characters like height of plant, number of leaves and number of branches. Full substitution of FYM with vermicompost resulted in highest vegative growth which was on par with 75 per cent vermicompost + 25 per cent FYM.

From an experiment conducted at College of Agriculture, Vellayani on the efficiency of vermicompost on growth and yield of okra, Ushakumari *et al.* (1999) observed that vermicompost application as an organic source along with full recommended dose of NPK increased the plant height and number of leaves $plant^{-1}$.

Study carried out by Manonmani and Anand (2002) at Thiruchirapalli found that root length, number of root hairs, length and breadth of the leaf and dry weight of okra were maximum when supplemented with vermicompost. Shanthi and Vijayakumari (2002) observed that root length and shoot length of bhindi were increased by NPK + vermicompost at 60 DAS whereas at 30 DAS, it was increased by NPK + FYM.

2.1.2 Effect of Vermicompost on Growth Characters of Crops

Reddy *et al.* (1998) observed that in pea, height of the plant at harvest, days to initial flowering, number of branches $plant^{-1}$ and number of fruits $plant^{-1}$ were maximum with 10 t vermicompost + 100 per cent recommended NPK.

Samawat *et al.* (2001) observed that in tomato effect of vermicompost was higher in root growth than shoot growth. Hashemtmajd *et al.* (2004) found that shoot and root dry matter of tomato was greatest when vermicompost was used as potting media.

Arancon *et al.* (2003) reported that there was significant increase in shoot weight and leaf area in pepper plants when treated with vermicompost compared to inorganic fertilizers only.

Experiment conducted by Sailajakumari (1999) at College of Agriculture, Vellayani reported that application of enriched vermicompost increased nodule number $plant^{-1}$, weight of nodules $plant^{-1}$and root-shoot ratio of cowpea. According to Rajkhowa *et al.* (2000) application of vermicompost showed positive effect on dry matter production, nodule number and root weight of green gram.

In a study conducted on effect of vermicompost on growth and yield of soybean, Thanunathan *et al.* (2002) found that vermicompost application increased the growth attributes such as plant height and leaf area index. According to Asewar *et al.* (2003) vermicompost application @ 2 t ha^{-1} increased the plant height and number of branches $plant^{-1}$ in chickpea. According to Jat and Ahlawat (2004) the vermicompost application @ 3 t ha^{-1} increased the growth parameters such as dry matter accumulation $plant^{-1}$, LAI and root weight in chick pea over no vermicompost.

Hiranmani *et al.* (2003) in a study on the effect of vermicompost with organic and inorganic manures found that vermicompost alone and admixed with FYM, green manure, neem cake and NPK fertilizers were effective in improving various biometric parameters like leaf area and dry matter production in chilli.

Reddy and Rao (2004) reported that application of 13.8 t ha^{-1} of vermicompost was found to increase the vine length and number of branches of bittergourd.

2.1.3 Effect of FYM on Growth Characters of Bhindi

Montasser (1991) found that the average length and fresh weight of shoot and root of okra increased considerably in cattle, pigeon, rabbit and sheep manure amended plots. In an experiment conducted by Naidu *et al.* (1999) found that plant height, number of leaves $plant^{-1}$, number of nodes $plant^{-1}$, internodal length of okra were maximum under NPK (80 : 60 : 50) + 20 t FYM ha^{-1}. In a study conducted by Raj (1999) at College of Agriculture, Vellayani on organic nutrition in okra revealed that plant height and LAI were highest for FYM + green leaf which also took minimum number of days for 50 per cent flowering.

Subbiah and Sunderarajan (1993) found that combined application of 12.5 t ha^{-1} FYM + recommended dose of macronutrients + 25 kg $ZnSO_4$ ha^{-1} in bhindi was better than FYM alone or combinations of 25 t ha^{-1}

FYM with the recommended dose of fertilizers with or without micronutrients.

A study conducted by Issac (1996) at College of Agriculture, Vellayani on yield, quality and vigour of bhindi seed as influenced by number of harvest and nutrient sources reported that application of 6 t ha^{-1} of FYM + chemical fertilizers resulted in increased biometric parameters such as plant height at 60 and 90 DAS, LAI at 30 DAS and 60 DAS and root spread at final harvest.

2.1.4 Effect of FYM on Growth Characters of Crops

Application of FYM resulted in higher vegetative mass, dry weight, plant weight and rate of dry matter increment per unit leaf area of capsicum (Cerna, 1980; Valsikova and Ivanic, 1982). They also reported that application of chemical fertilizers in the absence of FYM retarded the formation of vegetative organs and resulted in lower flower production. Reddy and Swamy (2000) reported that FYM application @ 10 t ha^{-1} increased dry matter accumulation $plant^{-1}$ in blackgram.

According to Renuka and Sankar (2001) vigorous growth of tomato with early flowering can be observed by the application of FYM + biogas slurry. Study conducted by Rafi *et al.* (2002) on effect of organic and inorganic fertilizers on growth and yield of tomato revealed that the plant height recorded at 90 DAS and number of primary branches were maximum in 50 per cent recommended dose of fertilizers + 50 per cent FYM. According to Reddy *et al.* (2002) application of 50 per cent nitrogen through FYM and 50 per cent N through urea recorded highest plant height and number of branches $plant^{-1}$ in tomato. Kumar and Sharma (2004) in a study on the integrated nutrient management for sustainable cabbage – tomato cropping sequence reported that in cabbage, application of FYM @ 10 t ha^{-1} + 150 per cent NPK resulted maximum plant height and in tomato, plant height and number of primary branches $plant^{-1}$ were maximum with 25 t ha^{-1} of FYM + 150 per cent NPK treatment.

Patil *et al.* (2004) had obtained greatest plant height, number of primary branches plant^{-1} and highest number of leaves plant^{-1} in tomato with the application of 50 per cent recommended fertilizer rate + 50 per cent FYM. Sharma and Sharma (2004) found that application of FYM (10 and 20 t ha^{-1}) in tomato significantly increased the plant height and number of branches plant^{-1} over no application.

Naidu *et al.* (2002) found that NPK @ 100 : 60 : 50 kg ha^{-1} + FYM @ 25 t ha^{-1} recorded highest value for plant height, number of leaves plant^{-1}, number of branches plant^{-1} in brinjal.

2.2 EFFECT OF DIFFERENT SOURCES OF ORGANIC MANURE ON YIELD CHARACTERS OF CROPS

2.2.1 Effect of Vermicompost on Yield Characters of Bhindi

From an experiment conducted by Ushakumari *et al.* (1999) at College of Agriculture, Vellayani observed that vermicompost application as an organic source (12 t ha^{-1}) along with full recommended dose of NPK increased number of fruits plant^{-1} and yield (kg ha^{-1}) of bhindi. Manonmani and Anand (2002) reported that yield of bhindi was maximum in plots supplemented with vermicompost.

2.2.2 Effect of Vermicompost on Yield Characters of Crops

In a study conducted by Pushpa (1996) on effect of vermicompost on yield and quality of tomato found increased yield attributes like mean fruit weight, girth of fruits and fruit yield with 25 t vermicompost along with full dose of inorganic fertilizers. Arancon (2003) reported that the tomato yield in all vermicompost treated plots were consistently greater than yields from inorganic fertilizer treated plots. In a study conducted by Patil *et al.* (2004) at Karnataka reported that the highest yield in tomato was observed with the recommended rate of inorganic fertilizer (NPK @ 100: 75: 100 kg ha^{-1}) + vermicompost @ 2 t ha^{-1}.

Dharmalingam *et al.* (1995) got 16 per cent increase in yield of soybean due to vermicompost pelleting over non pelleted seeds. Reddy and Mahesh (1995) observed significant increase in pod yield of green gram due to application of vermicompost and FYM over inorganic fertilizers. Reddy *et al.* (1998) revealed that number of pods plant^{-1} and yield in pea were highest with 10 t vermicompost + 100 per cent recommended NPK.A study conducted by Asewar *et al.* (2003) at Parbhani reported that application of vermicompost @ 2 t ha^{-1} increased pods plant^{-1}, grain yield and straw yield in chickpea compared to no vermicompost application. Jat and Ahlawat (2004) observed that vermicompost application @ 3 t ha^{-1} incurred yield attributes such as number of pods plant^{-1} and straw yields of chickpea over no vermicompost.

In a study on brinjal, Rao and Sankar (2001) reported highest fruit yield with FYM + vermicompost followed by FYM + neem cake. Hiranmani *et al.* (2003) reported better yield in chilli in vermicompost treated plots. In a study conducted by Reddy and Rao (2004) on growth and yield of bittergourd as influenced by vermicompost and nitrogen management practices revealed that application of 13.8 t ha^{-1} vermicompost was found to be beneficial in improving number of fruits vine^{-1} and fruit yield ha^{-1}. In a study conducted by Reddy and Rao (2004) on growth and yield of bittergourd as influenced by vermicompost and nitrogen management practices revealed that application of 13.8 t ha^{-1} vermicompost was found to be beneficial in improving number of fruits vine^{-1} and fruit yield ha^{-1}.

2.2.3 Effect of FYM on Yield Characters of Bhindi

Issac (1996) reported that increased green fruit yield ha^{-1} in bhindi was observed for 12 t FYM + chemical fertilizers while maximum mature fruit yield ha^{-1} was noticed both for 12 t FYM + chemical fertilizers and 6 t FYM + chemical fertilizers. Naidu *et al.* (1999) found that application of NPK @ 80: 60: 50 kg ha^{-1} + 20 t FYM ha^{-1} in bhindi resulted increased number of fruits $plant^{-1}$, weight of fruits $plant^{-1}$ and maximum fruit yield.

2.2.4 Effect of FYM on Yield Attributes of Crops

Subbiah *et al.* (1983) reported that yield of brinjal fruits was significantly influenced by the level of FYM, but not by the levels of fertilizer or by the interaction between FYM and inorganic fertilizers. Nair and Peter (1990) reported highest yield in chilli with 15 t FYM + 75:40:25 kg NPK ha^{-1} in the three seasons tried when compared to inorganic fertilizers alone. In a study conducted by Naidu *et al.* (2002) at Jabalpur reported that NPK at 75: 35: 0 kg ha^{-1} and FYM @ 25 t ha^{-1} in brinjal recorded highest fruit girth and earliest 50 per cent flowering but highest mean fruit yield was obtained with NPK @ 100 : 60 : 50 kg ha^{-1} and FYM @ 25 t ha^{-1}.

The results of a long term fertilizer experiment conducted at Tamil Nadu Agricultural University, Coimbatore in a mixed red medium black soil for a period of 16 years revealed that there was significant difference in the yield of finger millet, maize and cowpea due to FYM application (Muthuswamy *et al.*, 1990).

Ahmed (1993) reported that yield of tomato was greatest with FYM @ 19.01 t ha^{-1} followed by coirpith compared to control plot without these two manures. In an experiment conducted by Renuka and Sankar (2001) at Bapatla on effect of organic manures on growth and yield of tomato revealed that the application of FYM + biogas slurry, recorded an increased yield of two and half times over the control. Rafi *et al.* (2002) reported that in tomato the least number of days for 50 per cent flowering, maximum fruit set, fruit weight, number of fruits $plant^{-1}$ and the highest yield $plant^{-1}$ and ha^{-1} were observed when applied with 50 per cent recommended dose of fertilizers + 50 per cent FYM. Reddy *et al.* (2002) reported that application of 50 per cent N through FYM + 50 per cent N through urea recorded the highest number of fruits $plant^{-1}$, fruit weight and yield in tomato compared to all other treatments. Patil *et al.* (2004) reported that application of 50 per cent recommended fertilizer rate + 50 per cent FYM resulted in highest number of fruits plant^{-1}, average fruit weight and yield plant^{-1} in tomato. Sharma and Sharma (2004) revealed that application of FYM (10 and 20 t ha^{-1}) in tomato significantly increased number of fruits plant^{-1}, average fruit weight and fruit yield over no application.

In a study conducted by Joseph (1998) at College of Agriculture, Vellayani on evaluation of organic and inorganic sources of nutrients on yield and quality of snakegourd revealed that yield attributing characters like length of fruit, weight of fruit and number of fruits plant^{-1} were highest in plots applied with FYM + FYM to substitute NPK.

In an experiment carried out by Arunkumar (2000) at College of Agriculture, Vellayani on organic nutrition in Amaranthus revealed that FYM application was found to be superior to vermicompost in inducing better yield.

Apart from being the source of nutrients, FYM can increase the availability of insoluble phosphate and phenolic compounds (eg. Salicylic acid and vanillic acid) formed from organic matter. It also has favourable effect on plant growth and yield (Tirkey *et al.*, 2002).

2.2.5 Effect of Sources of Compost on Growth and Yield of Crops

Water hyacinth compost caused yield increase in different crops such as rice (Dhar, 1977; Kondap *et al.*, 1981; Kumaresan, 1984), wheat and potato (Dhar, 1977), groundnut (Kondap *et al.*, 1981; Kumaresan *et al.*, 1984) and chilli (Maurya and Dhar, 1990).

Kamath *et al.* (1991) revealed that applying 9 t water hyacinth compost ha^{-1} with 67.5 per cent recommended NPK would give the same yield in sorghum as the recommended NPK rate without water hyacinth compost.

Rabie *et al.* (1995) reported that applications of water hyacinth compost at 2.5 and 5t ha^{-1} enhanced dry matter yield in groundnut, maize and barley. According to Khandal and Bharadwaj (2002) plant height, dry matter production and grain yield of wheat cultivars were maximum at higher doses of water hyacinth vermicompost.

In a study to compare the different sources of organic manure *viz.*, aquatic weed compost and cow manure, Hossain and Majid (1997) observed that gourd yields were highest with 180 kg water hyacinth compost added per plant ling hole and tomato yields were higher with 1: 1 mixture of aquatic weed compost: cow manure than with cow manure alone. Thanunathan *et al.* (2002) reported that maximum grain yield in soybean was recorded with coirpith vermicompost and the yield was similar to enriched coirpith vermicompost and sugarcane trash vermicompost. Maximum values for plant height and leaf area index was recorded with coirpith vermicompost application @ 12.5 t ha^{-1}.

2.3 EFFECT OF DIFFERENT SOURCES OF ORGANIC MANURES ON SEED CHARACTERS OF CROPS

2.3.1 Effect of Vermicompost on Seed Characters of Crops

According to Pushpa (1996) a seed yield of 105 per cent with maximum germination count and viability of tomato seeds were obtained in plots, which received full inorganic fertilizer (as per POP recommendation of Kerala) and 25 t vermicompost. In a study conducted by Rotondo *et al.* (2003) on the effect of vermicompost and the organic fertilization in tomato seedlings revealed that vermicompost alone or in mixtures with chemical fertilizers recorded better seed germination and quality than other treatments.

Khandal and Bharadwaj (2002) reported that grain yield of wheat was maximum with the application of higher dose of water hyacinth vermicompost (20 per cent of the soil).

Meera (1998) reported that coating of seeds with vermicompost significantly influenced the grain yield of cowpea. Coating seeds with vermicompost combined with the application of full inorganic fertilizers and FYM as organic source recorded the highest grain yield. Reddy *et al.* (1998) revealed that number of seeds pod^{-1} in pea was maximum with 10 t vermicompost + 100 per cent recommended NPK. Amendment of compost prepared from on farm wastes improved seed yield of legumes (Lodha and Burman, 2000). Jat and Ahlawat (2004) reported that vermicompost application @ 3 t ha^{-1} increased seed yield of chickpea over no application.

A study conducted by Karmegam *et al.* (1999) on effect of vermicompost on the growth and yield of green gram reported that the germination efficiency of green gram was 93.33 per cent in the vermicompost applied plots compared to 84.17 7per cent in the control *i.e.*, biodigested slurry. Rajkhowa *et al.* (2000) reported that highest seed yield $plant^{-1}$ in green gram were obtained with the application of 75 per cent N as urea along with 5 t ha^{-1} vermicompost and it was on par with application of N as vermicompost. In an experiment carried out by Siag and Yadav (2004) at New Delhi on effect of vermicompost and fertilizers on productivity of gram and soil fertility revealed that application of vermicompost @ 3 t ha^{-1} resulted in maximum seed yield which was statistically on par with that recorded @ 2 t ha^{-1}.

2.3.2 Effect of FYM on Seed Characters of Crops

Rawankar *et al.* (1984) revealed that application of FYM produced significantly higher seed cotton yield by 41.1 per cent over its no application.

A combined application of FYM and fertilizer nitrogen was found to increase the protein content of grains in red gram (Muthuvel *et al.*, 1985), ragi (Chellamuthu *et al.*, 1987) and wheat (Patil *et al.*, 1993) than when either applied alone.

Naidu (1987) concluded that in cowpea cv. Co-4, application of FYM + NPK at 25 : 50 : 0 kg ha^{-1} recorded the highest fresh and dry weight of seed, seed volume, germination, vigour and dry weight of seedling. Bacchav and Sabale (1996) reported that seed yield and seed protein and oil contents were highest in soybean with 50 per cent each of urea and FYM. Sharma and Mishra (1997) reported an increase in seed yield due to application of FYM in soybean.

Issac (1996) reported that maximum weight of seeds $fruit^{-1}$ and maximum seed yield ha^{-1} in bhindi were observed for 12 t FYM + inorganic fertilizers. According to Raj (1999) FYM + neem cake recorded maximum germination percentage in okra.

FYM @ 10 t ha^{-1} increased seed yield of black gram by 6.5 per cent over no FYM application (Reddy and Swamy, 2000). In sweet basil, application of FYM (12.5 t ha^{-1}) resulted in highest seed yield ha^{-1} (Sundaraiya *et al.*, 2003).

2.4 VERMICOMPOST Vs. FYM

Reddy and Mahesh (1995) observed significant increase in number as well as weight of functional nodules in green gram due to application of vermicompost as compared to FYM and chemical fertilizers and also observed significant increase in dry matter production and grain yield due to vermicompost application. Karmegam *et al.* (1999) found that shoot length, root length, number of root nodules, fresh weight and dry weight of green gram were significantly higher in vermicompost treated plots compared to biodigested slurry. According to Satish *et al.* (2003) vermicompost application @ 2.5 and 5 t ha^{-1} resulted in higher yield in mungbean compared to FYM.

Govindan *et al.* (1995) reported that vermicompost application as a substitute for FYM along with fertilizer application and cultural operations as per POP of Kerala in bhindi increased number of fruits $plant^{-1}$, length of fruit (cm) and fresh weight of fruit (g plant^{-1}), of which 100 per cent vermicompost without FYM resulted in highest value of these parameters. Issac (1996) reported that highest number of vigorous seeds in bhindi was obtained with application of 12 t FYM + 11 t vermicompost.

In a study conducted by Pushpa (1996) on effect of vermicompost on yield and quality of tomato found that vermicompost application compared to FYM greatly influenced biometric observations such as height of plant, number of leaves etc.

Joseph (1998) observed that in snakegourd, growth characters *viz.*, weight of the root plant^{-1} and dry matter production ha^{-1} were highest in FYM treated plots as compared to poultry manure or vermicompost treated plants.

Niranjana (1998) reported that vermicompost produced significantly higher dry weight for amaranthus compared to FYM and POP of Kerala at 30 and 60 DAT. In a study conducted by Arunkumar (2000) on organic nutrition in amaranthus found that FYM application was found to be superior to vermicompost in inducing better plant height, root biomass production and leaf area index.

2.5 EFFECT OF ORGANIC LIQUID SPRAYS ON CROP GROWTH AND YIELD

Varshney and Gaur (1974) in a microplot experiment on the sandy loam alluvial parts of Delhi inoculated soybean and subsequent tomato crop were sprayed four times with 125 ml plot^{-1} of solution of sodium humate extracted from FYM. Sodium humate at 10 and 50 ppm increased the seed yield of soybean by 24 and 14.5 per cent respectively and also increased nitrogen uptake. Corresponding increase in tomato yield were 109 and 104 per cent.

Kadhum *et al.* (1980) reported that of the seven fertilizer treatments evaluated, yield were highest and the root and shoot growth were best in tomatoes receiving 6 l m^{-2} of a liquid organic fertilizer containing 60 g NPK (18: 18: 5).

Sarr and Ganry (1985) used rice husk compost at 7.5 t ha^{-1} + effluent (liquid produced during composting) gave tomato yields of 71.96 t ha^{-1} compared with 59.2 t ha^{-1} for control. He reported that any compost + effluent gave better yield than compost without effluent.

Liquid fraction of lignite used as an organic fertilizer increased fruit yield and reduced early fruiting in tomato (Salas *et al.*, 1986). Watery extracts from composted organic material greatly reduced disease development under lab condition in tomato leaves.

David *et al.* (1994) reported that addition of 1280 mg humic acid $litre^{-1}$ produced significant increase in accumulation of N, Cu, Fe and Zn in tomato seedlings. Fresh and dry weights were also increased. Humus preparation applied to soil increased and advanced fruit ripening in tomato by 4 to 5 days (Gonet and Cerny, 1996).

In a study conducted by Mashewari *et al.* (2003) at Annamalai on effect of foliar application of organic nutrients on some quality indices and economics of chilli reported that capsaicin content and seed number were highest (10.49) with 0.75 per cent amino acid + complete fertilizer dose.

Alkaff and Hassan (2003) on effect of biofertilizer, organic fertilizer and foliar application of Power 4 (trace element fertilizer) on okra plants revealed that foliar application of 4 g power $litre^{-1}$ had higher value for fresh dry matter, number of pods $plant^{-1}$, average yield, average fruit weight, early yield and total green fruits, while foliar application at 2 g $litre^{-1}$ gave the highest plant dry weight.

2.5.1 Effect of Vermiwash on Growth and Yield of Crops

Weekly application of diluted vermiliquid improved growth of radish and increased yield to around 20 per cent (Buckerfield *et al.*, 1999).

Jasmin (1999) reported that application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield of tomato. At higher concentrations (50 and 25 per cent) of vermiwash, fertilizers could be reduced to half of the recommended dose without any yield reduction.

Thangavel *et al.* (2003) in a study conducted on the effect of vermiwash and vermicast extracts on growth and yield of paddy observed that both vermiwash and vermicast extracts increased growth and yield of paddy.

Vermiwash spray enhanced the growth parameters viz. plant height, number of laterals, number of leaves and leaf area and yield parameters viz. number of days to flowering, number of flowers plant^{-1} in marigold. (Sivasubramanian and Ganeshkumar, 2004).

Study conducted by Venkataswara *et al.* (2005) on the effect of organic fertilizers on the yield of bhindi observed that vermiwash increased the growth by supplementing growth promoting substances like IAA and IBA. It also improved the yield, quality and resistance to pest and diseases and improved the soil health by conserving natural flora and fauna of soil.

2.5.2 Effect of Vermiwash on Seed Characters of Crops

Jasmin (1999) reported that foliar spraying of vermiwash produced significant effect on number of seeds fruit^{-1} compared to soil application and also produced seeds with more germination capacity.

2.6 EFFECT OF ORGANIC MANURES ON NUTRIENT UPTAKE AND AVAILABILITY

In wheat–maize rotation, available N and P content of the soil increased with continuous use of FYM (Prasad and Singh, 1980). Srivastava (1985) observed that increased use of nitrogenous fertilizers decreased organic carbon content and total N, while FYM increased the above parameters. More (1994) reported that addition of farm waste and organic manure increased the status of organic carbon, available N and available potassium of the soil. Isaac (1996) reported that application of 12 tonnes of FYM + 11 tonnes of vermicompost showed higher available N status and available 'K' status significantly superior to other sources of N. Addition of FYM or decomposed rice straw improved the N, P and K status of soil (Bandyopadhyay and Puste, 2002). According to Patidar *et al.* (2002) application of FYM on the sorghum field increased the available N and P content of soil.

Dhargawe *et al.* (1991) observed a significant increase in P availability in soil following the application of FYM. Gaur (1994) reported that humus by virtue of its chelating properties increased the availability of N, P, S and other nutrients to plants growing in humus rich soils. The humus increases 'P' availability as they have very high exchange capacity. Reddy and Mahesh (1995) observed that available P of soil was increased by the application of vermicompost compared to FYM. Apart from being the source of nutrients, FYM can increase the availability of insoluble phosphate (Tirkey *et al.*, 2002).

Available K increased slightly with the addition of FYM for a long time (Sharma *et al.*, 1984). Sharma and Sharma (1988) compared the effect of FYM and green manure and inferred that there was a build up of available K which was maximum with the use of FYM than green manure. Dhanorkar *et al.* (1994) opined that continuous use of FYM increased available K by 1.3 to 5.4 folds over control.

Ganguly (1988) reported the beneficial effect of FYM on the uptake of nutrients on maize. Raju *et al.* (1991) observed FYM to be more effective in increasing N uptake in chickpea. Singh and Tomar (1991) found that application of FYM and K had a positive effect on the uptake of N by wheat crop. Minhas and Sood (1994) reported that FYM application was beneficial in enhancing the uptake of N, P and K by potato and maize. In bhindi, N and P uptake were highest for FYM + neem cake where as 'K' uptake was maximum for FYM + poultry manure with 150 kg ha^{-1} of N and with azospirillum inoculation. The available N, P and K status of soil were highest in FYM + neem cake, FYM + enriched compost and FYM alone treated plots respectively with 150 kg $ha^{-1}$of N and azospirillum inoculation (Raj, 1999). Sharma *et al.* (2001) reported that conjoint use of N along with FYM markedly influence N, P and K uptake, which might be due to the supply of this nutrients and improvement of soil physical properties for better plant growth. FYM along with different levels of S, Mo, Fe, Zn and Co increased the uptake of major and micro nutrients by cowpea at harvest (Sharma *et al.*, 2002).

Khan *et al.* (1981) reported that city compost raised the Zn and iron content of the plants from deficiency to sufficiency level. Pandiyan (1990) proved the impact of composted coir pith on the retention of water soluble phosphate. Connel *et al.* (1993) observed an increase in the available N content of the soil by the application of municipal solid waste. Ammal and Muthiah (1994) reported that application of composted coir pith plus 'K' recorded the highest uptake of K by rice plants compared with raw coir pith plus K or K alone. According to Bansal *et al.* (1999), maximum N and P uptake in mung bean were given by compost prepared from a 3:7 mixture of cattle manure and rice straw inoculated with earth worms. Cuevas *et al.* (2000) reported that application of dried composted municipal solid waste to a degraded semiarid shrub land significantly increased the availability of P, K, nitrate N and EC. It also increased the concentration of total soluble heavy metals like Zn, Pb, Cd, Ni, Cr and Cu. Application of household compost and solid pig manure showed an increased accumulation of N and P and also resulted in stimulation of some biological activity (Peterser *et al.*, 2003).

Balaji (1994) recorded higher levels of total N, available P and K in treatments which received either vermicompost alone or in combination with FYM or chemical fertilizers than control. Chaudhuri *et al.* (2001)

reported that higher concentration of total N, available P, K and Ca were present in aquatic weed vermicompost when aquatic weed get composted by *Perionyx excavatus*. Talukdar *et al.* (2001) reported that K content was highest in water hyacinth vermicompost. According to Kanwar and Paliyal (2002), application of FYM and vermicompost were equally effective in increasing the available P status of soil. Water hyacinth compost enhanced the 'P' availability due to the presence of organic acids (Mani and Perumal, 2002). Thanunathan *et al.* (2002) reported increase in N availability and uptake due to vermicompost application in soybean.

An experiment conducted by Shuxin *et al.* (1991) reported that 30 to 50 percent increase in N uptake in vermicompost applied sugar cane. Pushpa (1996) reported an increased uptake of plant nutrients when vermicompost was used as a source of organic manure than FYM. According to Meera (1998), use of vermicompost coated seeds produced the maximum uptake of N, P and K at peak flowering stage and harvest. Soil analysis for available nutrients revealed that the different treatments had significant influence on Ca, Mg, Zn, Cu and Mn content in soil. Martinez *et al.* (1999) reported that P content of foliage in chilli was increased when mycorrhizal fungi and vermicompost were applied. Rajkhowa *et al.* (2000) reported that N applied through vermicompost increased the plant P and K content by 13.5 and 32.5 percent respectively over control in green gram. Vermicompost contained different growth promoting substances which induced high dry matter yield in rice leading to higher uptake of nutrients (Banik and Ranjita, 2004).

Padmaja *et al.* (1998) reported that vermiwash contains an average 200 ppm N, 70 ppm P and 1000 ppm K and other nutrients. Jasmin (1999) reported that plant uptake of major and micronutrients were maximum for the highest concentration of vermiwash applied through foliage along with full inorganic fertilizers. Karuna *et al.* (1999) reported that there will be continuous supply of P in available form from vermiwash along with P supplied through inorganic fertilizers. According to Hangarge *et al.* (2004), application of vermicompost @ 5t ha^{-1} + organic booster @ 1 litre m^{-2} enhanced the availability of N, P, K and organic C content in soil.

2.7 CROP RESPONSE TO AMF

AMF play an important role in water economy of plants. It improves conductivity of roots, which contribute to better uptake of water (Levy and Krikun, 1980). Mycorrhizal fungi are the key components of soil micro biota. They are obligate symbionts and are root host specific (Bonfante–Fasolo, 1987).

AMF impart enormous benefits to the plant community both in the natural ecosystem and in the different agricultural situations. It has been widely used as a bioinoculant for sustaining the growth and health of cultivated crops (Rosendahl *et al.*, 1992). The VAM association increases the growth, nutrient uptake and resistance to root diseases in crop plants (Sivaprasad *et al.*, 1990).

2.7.1 Effect of AMF on Growth and Yield of Crops

The positive response to growth of plants in association to VAM has been widely reported (Mosse, 1973: Tinker, 1975). Hayman, 1983; and Jeffries, 1987 have reported that mycorrhizal association improved the growth in a wide range of plants. AMF inoculation increased growth and yield of rice (Hernandez and Cuevas, 1999).

In a study conducted by Senapathi *et al.* (1987) found that AMF inoculated bhindi plants produced taller plants with more number of seeds pod^{-1}. Pre-inoculation of okra seeds with AMF resulted an enhanced growth and yield of crop (Jothi *et al.*, 2000). In a study conducted by Bahadur and Manohar (2001) on response of okra to biofertilizers revealed that application of VAM + recommended dose of NK produced comparatively higher pod length and pod diameter over other treatments.

According to Lu and Koide (1994) mycorrhizal plants had much greater leaf area, leaf weight and more number of leaves. Solaiman and Hirata (1997) reported that rice plants inoculated with AMF produced higher biomass at maturity, and grain yield was 14 to 21 percent higher than that of uninoculated plants. Purakayastha and Chhonkar (2001) reported that AMF inoculation in rice enhanced the root length, root volume and total uptake of Zn and increased grain and dry matter yields. In an experiment conducted at Central Rainfed Upland Rice Research Station, Hazaribag, mycorrhizal colonization enhanced the yield attributing characters like leaf area index, tiller number and panicle number in rice (Rana *et al.*, 2002). A study conducted by Jayakiran (2004) at College of Agriculture found that AMF inoculated rice plants showed superior trend in plant height, leaf area index, dry matter production, grain yield and straw yield.

Mycorrhized saplings show significant increase in root length, lateral roots and plant dry biomass over non mycorrhized saplings in mulberry (Setua *et al.*, 1999). Sinha *et al.* (2000) noticed that the dry weight and root colonization were higher in AMF treated transplanted rice cultivars than those without the treatment, the uptake of P were significantly higher with the AMF and the plant growth was also better. Devi and Sitaramaiah (2001) observed that black gram inoculated with mycorrhizal fungi showed more shoot and root dry weight and chlorophyll content.

Nagaraju *et al.* (2000) revealed the VAM inoculated onion plants receiving 50 per cent P_2O_5 showed significant increase in plant height, number of leaves, number of tillers, bulb diameter and weight of bulbs when compared to plants that were supplemented with 100 per cent P and with no VAM inoculation.

Inoculation of cowpea with mycorrhizae alone or in combination with azotobacter increased the plant height as compared to control and also recorded maximum number of nodules as well nodule dry weight (Kumar *et al.*, 2001). Dual inoculation of AMF and PSM at 30 kg P_2O_5 ha^{-1} gave the maximum number of pods $plant^{-1}$ and haulm yield in vegetable cowpea (Mathew and Hameed, 2003).

AMF increased the plant growth in terms of shoot length, root length, shoot weight and root weight in cotton (Sreenivasan *et al.*, 2004).

2.7.2 Effect of AMF on Seed Characters

Cowpea plant inoculated with mycorrhizae provided highest seed germination (Kumar *et al.*, 2001). In a study conducted by Prabhu *et al.* (2003) on effect of integrated nutrient management on growth and yield of okra revealed that germination of okra seeds increased when inoculated with bio fertilizers.

2.7.3 Nutrient Uptake and Transfer through Mycorrhiza

The symbiotic association between Mycorrhizal fungi and plants is beneficial to the plant in terms of better nutrient uptake (Mosse, 1973), high water potential (Sanchez – Dias and Honrubia, 1994) and lesser chances of root diseases (Newsham *et al.*, 1995) which led the plants more healthy and productive in comparison to non Mycorrhizal plants.

Tinker (1975) reported the role of AMF in plant growth and nutrient uptake. Inoculation of AMF beneficial to crops by way of mobilising nutrients especially P (Hayman, 1983; Bolan, 1991; Verma and Schuepp, 1995; Sekhar *et al.*, 1997).

VAM can solubilize non available form of phosphate; also can make shorten the diffused path of available form of phosphate (Iqbal and Qureshi, 1977; Sulochana and Manoharachary, 1989; Bagyaraj and Manjumnath, 1980). It has been well documented that AMF association can act as a channel for direct interplant nutrient transfer of P (Heap and Newman, 1980), transfer of N (Kessel *et al.*, 1985) and carbon compounds (Greeves *et al.*, 1997) by arbuscular mycorrhizal hyphae.

Gangopadhyay and Das (1982) observed an increased uptake of N, P and K in AMF inoculated rice plants. Hayman (1983) observed that AM hyphae in organic connection with the root extend beyond the zone of phosphate depletion, which develops in phosphate deficient soils because the root absorbs phosphate ions faster than they can diffuse through soil to replenish the supply at the root surface. Bolan *et al.* (1984) observed that when the initial soil P concentration was very low, even a small addition of P tremendously increased colonization.

Experimental results of Young *et al.* (1986) have indicated that AMF in association with plant roots increased P uptake. Plants colonized by mycorrhizal fungi are more efficient in taking up soil P than non mycorrhizal plant (Smith, 1988). AMF colonization significantly increased nutrient uptake, particularly immobile or sparingly soluble forms of P by the host plant (Manjunath *et al.*, 1989).

Increase in 'K' uptake in treatments which received VAM was because of increase in uptake of several nutrients like Zn, S etc. (Paul and Clerk, 1989).Barea (1991) observed that VAM fungi enhanced plant growth as a result of improved mineral nutrition of the host especially immobile nutrients in the soil.

In spite of this, when heavy doses of P were applied it reduced root volume and in consequence it decreased the surface area colonized by AMF (Smith, 1982; Thompson *et al.*, 1991). Champawat (1992) reported enhanced shoot and root dry weight in chick pea due to mycorrhizal inoculations and P content in shoot and root were significantly more in inoculated plants than non inoculated plants. P availability is increased by application of VAM in lentil (Singh and Singh, 1993).

Rathore and Singh (1995) reported that VAM inoculation increased dry matter accumulation and NPK uptake by maize besides increasing the available soil P. The enhanced uptake of P and other nutrients has been well documented in crops like cassava, cardamom, ginger, turmeric, cashew and legumes grown in 'P' fixing soils of Kerala (Sivaprasad *et al.*, 1990; Geethakumari *et al.*, 1994). Garcia – Gil *et al.* (1999) reported that mycorrhizal inoculation decreased the phosphatase activity by 43 per cent compared with non mycorrhizal plants. In maize, Banerjee *et al.* (1999) reported that AMF generally enhances uptake and translocation of P and encourages plant growth and development in nutrient deficient soils.

Availability of nutrients like P, N, Zn, Cu, K, Ca and Mg are enhanced in acidic soils (Clark and Zeto, 2000). Gill *et al.* (2000) observed that AMF have an important effect on plant P uptake and availability of other elements like Zn, Cu, manganese, K, sodium, Mg, iron etc. Mycorrhizae inhabit roots of several crops and solubilize soil phosphates.

AMF significantly stimulated growth, dry matter, nodulation, shoot and root length, shoot and root dry weight and higher uptake of nutrients in green gram (Hazarika *et al.*, 2000). Pare *et al.* (2000) reported that N recovery and mineralization from crop residues by maize was enhanced by inoculation with AMF fungi.

According to Devi and Sitaramaiah, 2001 the chemical composition of N, P, K, Ca and Mg in black gram increased with increasing inoculum density of AMF.The beneficial effect of AMF association in the host nutrition in the uptake of P is well documented in pepper mint (Khaliq *et al.*, 2001). He also reported that uptake of other nutrients viz. Cu, Zn, K, Fe, Mn were also well documented.

Rea and Tullio (2001) reported that AMF can be considered as biological fertilizers. They improve the host plant's water and nutritional conditions and are a valid help to chemical fertilizers in achieving yield and at the same time preserving the environment.

Hildebrandt *et al.* (2002) AMF colonization positively affects nitrate uptake from the soil and nitrate allocation to plant parts in tomato. Jayakiran (2004) reported that N, P and K uptake by rice significantly increased when applied with AMF. Singh *et al.* (2004) reported that N as well as P uptake by okra was highest and increased significantly in treatment which received VAM with inorganic fertilizer.

2.8 EFFECT OF DIFFERENT SOURCES OF ORGANIC MANURES, VERMIWASH AND AMF ON PEST AND DISEASE INCIDENCE

Application of vermicompost in groundnut decreased the damage caused by jassid and thrips compared to fertilizer applied plots and the decreased damage was due to the presence of higher levels of K_2O in the vermicompost (Bhatnagar and Palta, 1996).

A study conducted by Jothi *et al.* (2000) observed that pre inoculation of okra seeds with AMF reduced *Meloidogyne incognita* population. Among the organic manures, FYM and vermicompost resulted the lowest percentage of shoot and fruit borer infestation in bhindi plants (Prakash *et al.*, 2002). A study conducted by Venkataswara *et al.* (2005) on the effect of organic fertilizers on the yield of bhindi observed that vermicompost application increased resistance to pest and diseases.

Sabarad *et al.* (2004) reported the lowest nematode population of 70 and 148 per $200cm^3$ of soil with the application of vermicompost + 75 per cent recommended dose of fertilizers with and without VAM respectively.

2.9 EFFECT OF ORGANIC MANURE ON ECONOMICS OF CULTIVATION

Maximum net profit ha^{-1} in hybrid sorghum was obtained under the treatment combination of 9 tonnes of water hyacinth ha^{-1} and recommended fertilizer dose of 100:75:37.5 NPK ha^{-1} (Kamath *et al.*, 1991).

Patil *et al.* (1998) reported that highest net returns and BC ratio in tomato were obtained with vermicompost @ 2t ha^{-1} + NPK @ 100:75:100 kg ha^{-1} and vermicompost @ 4t ha^{-1} +recommended dose of inorganic fertilizers. Ushakumari *et al.* (1999) reported that application of vermicompost as an organic source, or in situ application of worms, significantly reduced the cost of okra production.

2.10 EFFECT OF COMBINED APPLICATION OF VERMICOMPOST OR FYM WITH BIOFERTILISERS ON GROWTH AND YIELD OF CROPS

Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like N fixers and mycorrhizal fungi. It played a significant role in N fixation and phosphate mobilisation, leading to higher nutrient uptake by plants. Naidu *et al.* (1999) reported that application of vermicompost with biofertilizers harboured significantly more microbes in soil than the control.

A study conducted by Martinez *et al.* (1999) on effect of vermicompost and mycorrhizal fungi on growth and photosynthetic rate of chilli revealed that the foliar area, dry shoot weight, radical volume and P content of foliage were increased when mycorrhizal fungi and vermicompost were applied.

An experiment conducted by Patil *et al.* (2000) on effect of organic manures and biofertilizers on yield and quality of okra revealed that application of biofertilizers (1 litre slurry)+FYM +50 kgN ha^{-1} was beneficial for obtaining higher yields of export quality pods when compared to their individual application.

A study conducted by Nuruzzaman *et al.* (2003) on effect of bio fertilizers on vegetative growth of okra revealed that plant height, number of leaves $plant^{-1}$, stem base diameter, root length, root dry weight and leaf area index were highest with application of azotobacter + 5 t cowdung ha^{-1}, azospirillum +5 t cowdung ha^{-1} and azotobacter + azospirillum +5 t cowdung ha^{-1}.

Prabhu *et al.* (2003) revealed that application of FYM and biofertilizers along with reduced dose of inorganic fertilizers (2/3 recommended dose of fertilizers) + FYM + azospirillum + VAM in okra found to increase the growth attributes like the number of leaves, leaf area and fresh and dry weight of plants and yield attributes like days to 50 per cent flowering, number of fruits $plant^{-1}$, fruit weight and marketable yield ha^{-1}. Application of FYM based inoculums of mycorrhizal fungi helped banana crop by increasing their yield by 20 -30 per cent (Geeta, 2004).

Sajitha and Haripriya (2004) reported that incorporation of press mud based vermicompost @ 5t ha^{-1} along with Rhizobium, *Glomus fasciculatum* and spraying vermiwash (4 times) registered highest green pod yield $plant^{-1}$ and yield $plot^{-1}$ in garden bean.

2.10.1 Effect of Combined Application of FYM or Vermicompost with Biofertilizers on Seed Characters

According to Chinnamuthu and Venkatakrishnan (2001), application of NPK at 50 per cent +vermicompost + VAM produced higher seed yield in sun flower than NPK at 50 per cent + FYM +VAM.

An experiment carried out by Panwar *et al.* (2002) on yield and quality of ground nut seed as influenced by P. bio fertilizers and organic manures revealed that highest seed yield and values of seed quality parameters being recorded with the application of FYM @ 5t ha^{-1} in the presence of Rhizobium and P solubilising micro organisms.

Materials and Methods

3. MATERIALS AND METHODS

An experiment was conducted at College of Agriculture, Vellayani to study the effect of vermicompost, vermiwash and AMF on quality seed production of bhindi from June 2004 to September 2004. The details of the materials used and methods adopted are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out at the Instructional Farm attached to the College of Agriculture, Vellayani situated at 8.5°N latitude and 76.9°E longitude and at an altitude of 29 m above mean sea level.

3.1.1 Soil

The soil of the experimental site was lateritic red loam belonging to the order oxisol of Vellayani series. The important physicochemical properties of the soil and the methods adopted for the analysis are presented in Table 1

Table 1. Soil characteristics of the experimental field

A. Physical composition

Sl. No.	Parameter	Content in soil (per cent)	Methods used
1	Coarse sand	31.60	Bouyoucos hydrometer method. (Bouyoucos, 1962)
2	Fine sand	19.20	
3	Silt	21.40	
4	clay	27.80	

B. Chemical composition

Sl. No.	Parameter	Content	Rating	Methods used
1	pH	4.8	Acidic	pH meter with glass electrode (Jackson, 1973)
2	Available N (kg ha^{-1})	242.65	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
3	Available P_2O_5 (kg ha^{-1})	39.7	Medium	Bray colorimetric method (Jackson, 1973)
4	Available K2O (kg ha^{-1})	97.28	Low	Neutral normal ammonium acetate method (Jackson, 1973)

3.1.2 Cropping History of the Field

The experimental area was kept fallow for two months before the experiment. Before that it was under cucumber cultivation.

3.1.3 Season

The experiment was conducted during June to September of 2004.

3.1.4 Weather Conditions

The weekly averages of the weather parameters viz. maximum and minimum temperature, relative humidity and rainfall received during the cropping period collected from the meteorological observatory of the College of Agriculture, Vellayani are given in the Appendix I and illustrated in Fig.1.

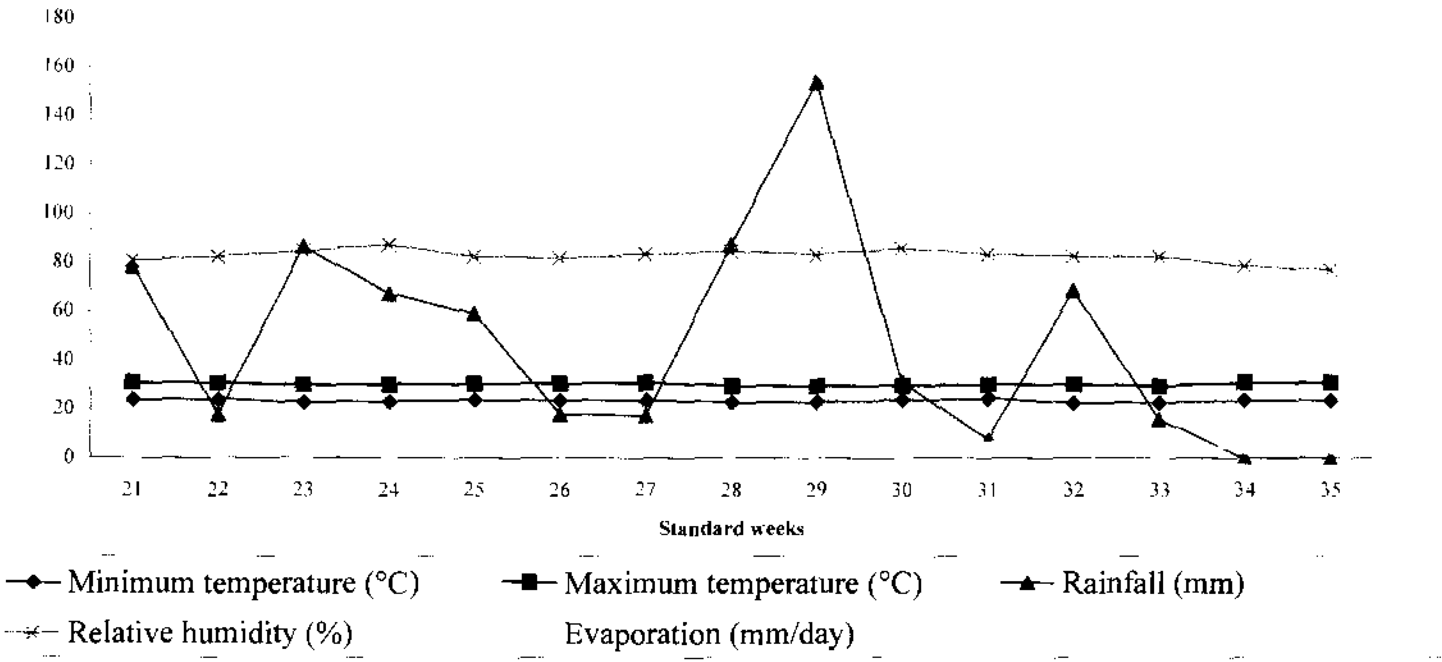


Fig. 1. Weather parameters during the cropping period (2nd June – 2nd September 2004)

3.2 MATERIALS

3.2.1 Cultivar Used

The cultivar of bhindi used for the study was Varsha Uphar which was released by CCS Haryana Agricultural University, Hissar by inter-varietal hybridization between 'Lam selection-1' and 'Parbhani Kranti' following pedigree selection in 1996. It is an early, high yielding variety, resistant to yellow vein mosaic disease.

3.2.2 Seeds

Seeds of variety 'Varsha Uphar' were obtained from the Instructional farm, College of Agriculture, Vellayani.

3.2.3 Mycorrhizal Inoculum

Mycorrhizal inoculum was obtained from Department of Plant Pathology, College of Agriculture, Vellayani.

3.2.4 Manures and Fertilizers

Farmyard manure (0.9 per cent N), Aquatic weed vermicompost (Spirogyra sp) (1.9 per cent N) and Banana pseudostem vermicompost (0.6 per cent N) along with vermiwash were used as organic sources of nitrogen and urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) as the inorganic sources of nitrogen, phosphorus and potassium respectively.

3.3 METHODS

3.3.1 Design and Layout (Fig.2)

General view of the experimental field is given in Plate 1.

Design	:	Split plot design
Number of main plot treatments	:	12
Number of sub plot treatments	:	2
Number of replications	:	2
Gross plot size	:	4.20 x 3.60 m^2
Net plot size	:	3.00 x 2.70 m^2

Plate 1. General view of the experimental field

N

$V_1W_1A_0$	$V_1W_2A_1$	$V_1W_3A_0$	$V_1W_4A_1$	$V_1W_1A_1$	$V_1W_2A_0$	$V_1W_3A_1$	$V_1W_4A_0$	
$V_2W_2A_1$	$V_2W_2A_0$	$V_2W_3A_1$	$V_2W_4A_0$	$V_2W_2A_0$	$V_2W_2A_1$	$V_2W_3A_0$	$V_2W_4A_1$	R_1
$V_3W_1A_0$	$V_3W_2A_1$	$V_3W_3A_1$	$V_3W_4A_0$	$V_3W_1A_1$	$V_3W_2A_0$	$V_3W_3A_0$	$V_3W_4A_1$	

$V_3W_1A_1$	$V_3W_2A_0$	$V_3W_3A_0$	$V_3W_4A_1$	$V_3W_1A_0$	$V_3W_2A_1$	$V_3W_3A_1$	$V_3W_4A_0$	
$V_2W_2A_0$	$V_2W_2A_1$	$V_2W_3A_0$	$V_2W_4A_1$	$V_2W_2A_1$	$V_2W_2A_0$	$V_2W_3A_1$	$V_2W_4A_0$	R_2
$V_1W_1A_1$	$V_1W_2A_0$	$V_1W_3A_1$	$V_1W_4A_0$	$V_1W_1A_0$	$V_1W_2A_1$	$V_1W_3A_0$	$V_1W_4A_1$	

V_1 – Aquatic weed vermicompost (N equivalent to 12 tonnes of FYM ha^{-1})

V_2 – Banana pseudostem vermicompost (N equivalent to 12 tonnes of FYM ha^{-1})

V_3 – FYM – 12 tonnes ha^{-1}

W_1 – Soil application (50ml vermiwash at equal splits)

W_2 – Foliar application (50 ml vermiwash at equal splits as sprays)

W_3 – Soil application + foliar application (50ml vermiwash each as soil application and foliar application)

W_4 – Water spray (control)

A_1 – with AMF application

A_0 – without AMF application

Fig. 2. Layout plan of the experiment

Spacing	:	60 x 45 cm^2
Total number of plots	:	48

3.3.2 Treatments

Main plot treatments (combination of vermicompost and vermiwash)

A) Organic manure

V_1 – Aquatic weed vermicompost (N equivalent to 12 tonnes of FYM ha^{-1})

V_2 – Banana pseudostem vermicompost (N equivalent to 12 tonnes of FYM ha^{-1})

V_3 – FYM – 12 tonnes ha^{-1}

B) Vermiwash

W_1 – Soil application (50 ml vermiwash at equal splits)

W_2 – Foliar application (50 ml vermiwash at equal splits as sprays)

W_3 – Soil application + foliar application (50 ml vermiwash as soil application + 50 ml vermiwash as foliar application)

W_4 – Water spray (control)

Sub plot treatment : AMF application

A_1– with AMF application

A_0– without AMF application

Treatment combinations

$V_1W_1A_0$	$V_2W_1A_0$	$V_3W_1A_0$
$V_1W_1A_1$	$V_2W_1A_1$	$V_3W_1A_1$
$V_1W_2A_0$	$V_2W_2A_0$	$V_3W_2A_0$
$V_1W_2A_1$	$V_2W_2A_1$	$V_3W_2A_1$
$V_1W_3A_0$	$V_2W_3A_0$	$V_3W_3A_0$
$V_1W_3A_1$	$V_2W_3A_1$	$V_3W_3A_1$
$V_1W_4A_0$	$V_2W_4A_0$	$V_4W_4A_0$
$V_1W_4A_1$	$V_2W_4A_1$	$V_4W_4A_1$

3.4 CROP HUSBANDRY

3.4.1 Land Preparation

The experimental area was first cleared of weeds and stubbles. The field was laid out as per the design and individual plots were dug well and levelled. In the plots of size 3.00 x 2.70 m^2, pits were taken at 60 x 45 cm^2 spacing.

3.4.2 Application of Manures and Fertilizers

Banana pseudostem vermicompost (N equivalent to 12 t of FYM ha^{-1}), aquatic weed vermicompost (N equivalent to 12 t of FYM ha^{-1}) and FYM (12 t ha^{-1}) were applied to the plots as specified in the technical programme as basal dose. Along with that, vermiwash was applied at 15 days interval from 15 days after sowing (DAS) onwards according to treatment specification. The inorganic fertilizers such as urea, mussoriephos and muriate of potash were applied uniformly to all plots as per POP recommendations of the Kerala Agricultural University. Half N, full P and full K were applied as basal and the remaining half dose of N was applied as top dressing at 30 DAS.

3.4.3 Application of AMF

AMF inoculum was applied @ five g pit^{-1}. It was placed as a layer on the soil surface and seeds are sown on this layer.

3.4.5 Harvest

Harvesting for seeds commenced from 65 DAS and was repeated on alternate days. Maturity of fruits for seed harvest was decided by visual observation (*i.e.*, drying and cracking of fruits along the ridges).

3.5 OBSERVATIONS

Biometric observations

Ten plants were selected as observational plants after eliminating the border rows from each plot. Of this ten plants biometric observations and fruit characters were recorded from five plants and from the remaining five plants seed characters like number of seeds fruit $^{-1}$, weight of seeds fruit $^{-1}$ and seed yield (kg ha^{-1}) and quality aspects like seed viability, vigour index and germination percentage were worked out. Random samples were selected for destructive sampling for dry weight observations.

3.5.1 Growth Characters

3.5.1.1 Height of the Plant

From the observational plants, the height was measured from the base to the terminal bud and the average was worked out and expressed in cm.

3.5.1.2 Number of Leaves

From the observational plants, the number of leaves was noted and average was worked out.

3.5.1.3 Leaf Area Index (LAI)

LAI was worked out using the formula suggested by Watson (1952) at 30 days interval.

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

3.5.1.4 Number of Branches Plant^{-1}

The number of branches plant^{-1} was recorded from the observation plants at 30, 60 and 90 DAS and average was worked out.

3.5.1.5 Dry Matter Production

Dry matter production was recorded at 30, 60 and 90 DAS. Sample plants were randomly selected. Plants were cut close to the ground and oven dried at 60 °C to a constant weight and expressed in kg ha^{-1}.

3.5.2 Root Characteristics

3.5.2.1 Length of Taproot

Length of taproot was recorded at final harvest from observational plants after uprooting them.

3.5.2.2 Root Spread

The observational plants were uprooted at final harvest and the lateral roots were spread over a plain paper. The length of the longest lateral root on both sides of the taproot was measured using a scale, the mean worked out and expressed in cm.

3.5.2.3 Root Shoot Ratio

Both fresh and dry weights of the root and shoot were taken and root-shoot ratio was calculated.

3.5.2.4 Root Colonization per cent of AMF

Plants were selected at random from respective plots and the roots were washed well in tap water to remove the dirt and clay particles. The mycorrhizal colonization in root was estimated following the procedure of Phillips and Hayman (1970). The well cleaned root samples were cut into one cm size bits and fixed in FAA (Formaldehyde–Acetic acid–Alcohol) in 5: 5: 90 proportions. The roots were hydrolysed in 10 per cent potassium hydroxide at 100 °C for 10-15 min. The alkanity of the samples was then neutralised by washing in one per cent hydrochloric acid and the root bits were stained with 0.05 per cent trypan blue in lactophenol (lactic acid 20 ml, phenol 20 ml, glycerol 40 ml and distilled water 20 ml). The stained roots were arranged on a clean slide, pressed with another clear slide and observed under medium power of the microscope for the presence of mycelium, vesicles and arbuscules. A minimum of 25 root bits from each sample were observed and percentage infection was recorded in different treatment combinations.

AMF colonization (per cent)

$$= \frac{\text{Number of root bits positive for AMF colonization}}{\text{Total number of root bits observed}} \times 100$$

3.5.3 Yield Attributes

3.5.3.1 Days for 50 per cent Flowering

Total number of plants flowered were counted daily in each plot and the date on which 50 per cent of plants flowered was taken as the days for 50 per cent flowering.

3.5.3.2 Number of Flowers Plant^{-1}

Total number of flowers from the five selected plants was counted and the average was worked out to get the number of flowers formed plant^{-1}.

3.5.3.3 Number of Fruits Plant^{-1}

Total number of fruits obtained from five observational plants was counted and average was worked out.

3.5.3.4 Setting Percentage

From the observational plants total number of flowers bloomed and the number of fruits formed were found out and setting percentage was calculated

3.5.3.5 Height of the First Bearing Node

The height of the node at which the first fruit was formed was measured from the ground level in all observation plants and their mean was worked out and expressed in cm.

3.5.3.6 Length of the Fruit

The length of the 20 fruits harvested from the observational plants in each harvest was measured, the mean worked out and expressed in cm.

3.5.3.7 Girth of the Fruit

The same fruits used for measuring the length were used for finding the girth. Measurement was effected by winding a thread around individual fruits. The mean values were worked out and expressed in cm.

3.5.3.8 Fruit Yield Plant^{-1} (g plant^{-1})

The weight of fruit obtained from the observational plants was recorded at each harvest. The total weight of the fruits plant^{-1} from different harvests was calculated and expressed as the fruit yield plant^{-1}.

3.5.3.9 Total Fruit Yield (q ha^{-1})

Weight of fruits from each harvest was summed up at the end of the cropping season and the yield in quintal plot^{-1} was calculated and converted into ha^{-1} yield.

3.5.3.10 Number of Seeds Fruit^{-1}

Twenty fruits were taken from the observational plants at random. the number of seeds was counted and the average worked out.

3.5.3.11 Weight of Seeds Fruit^{-1}

The fruits used to record the number of seeds fruit^{-1} were used for noting the weight of seeds fruit^{-1}.

3.5.3.12 Seed Yield (kg ha^{-1})

The total weight of seeds from the net plot area was calculated at the end of the cropping season and the yield in kg ha^{-1} was computed.

3.5.4 Quality Aspects of Seed

3.5.4.1 Seed Viability

Seed viability test was done using topographical tetrazolium chloride method. Ten seeds of each treatment were preconditioned by soaking in water for 12 hours, dissected longitudinally through the embryo and then kept in 0.1 per cent colourless tetrazolium chloride solution. Living tissues attained a red stain in tetrazolium solution indicating viability of seeds.

3.5.4.2 Vigour Index

Seedling vigour index (VI) was calculated by adopting the formula suggested by Baki and Anderson (1973) and expressed as a number.

VI = Germination per cent × (root length + shoot length)

3.5.4.3 Germination Percentage

Pure seed fraction of the different treatments was tested for germination. Twenty seeds per treatment were sown on Whatman No. 1 filter paper in Petri dishes of nine cm size. The paper was kept moist until the final count was taken on the 21st day. The number of seeds germinated was counted on the last day and the percentage worked out.

3.5.5 Plant Analysis

Sample plants collected from each plot at harvest were chopped, sun dried and oven dried to a constant weight. Samples were ground to pass through 0.5 mm mesh in a Willey Mill and the required quantity of samples were digested and used for nutrient content analysis.

3.5.5.1 Uptake of Nitrogen

The nitrogen content in plant sample was estimated separately by the modified microkjeldhal method (Jackson, 1973) and the uptake of nitrogen was calculated by multiplying the nitrogen content of plant with the total dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.5.5.2 Uptake of Phosphorus

The phosphorus content in the plant sample was colorimetrically determined separately by wet digestion of the sample and developing colour by Vanado-molybdo phosphoric yellow colour method and read in a Baush and Lomb Spectronic 2000 Spectrophotometer (Jackson, 1973). The uptake of phosphorus was calculated by multiplying the phosphorus content and dry weight of plants as the case may be. The uptake values were expressed in kg ha^{-1}.

3.5.5.3 Uptake of Potassium

The potassium content in plant sample was estimated separately by the Flame photometric method (Jackson, 1973) after wet digestion of the sample using di-acid mixture. Based on the potassium content in the plant and the dry matter produced at harvest, the uptake was worked out and expressed in kg ha^{-1}.

3.5.6 Soil Analysis

Soil samples were taken from the experiential area before and after the experiment. The air dried samples were analysed for available nitrogen by the alkaline potassium permanganate method (Subbiah and Asija, 1956) available P_2O_5 by Bray's colorimetric method and available K_2O by the ammonium acetate method (Jackson, 1973).

3.5.7 Incidence of Pests and Diseases

The incidence of leaf roller and cercospora leaf spot did not reached the threshold level and hence uniform score was given to all plots.

In the case of fruit and shoot borer, percentage of damaged fruits harvest^{-1} was calculated following the method of Gupta and Yadav (1978) as detailed below.

$$\text{Percentage of damaged fruits harvest}^{-1} = \frac{\text{Weight of damaged fruits plot}^{-1}}{\text{Total weight of fruits plot}^{-1}} \times 100$$

3.5.8 Economics of Seed Production

The economics of seed production of the experiment was worked out as per the formulae given below.

$$\text{BC ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.5.9 Statistical Analysis

The data relating to each character in the experiment was analysed using the analysis of variance (Panse and Sukhatme, 1967). Whenever the results were significant, the critical difference was worked out at five or one per cent probability.

Results

4. RESULTS

Field experiment to study the effect of vermicompost, vermiwash and AMF on quality seed production of bhindi was conducted at the Instructional Farm attached to College of Agriculture, Vellayani during the period from June to September 2004. The experimental data collected were statistically analyzed and results obtained are presented below.

4.1 GROWTH CHARACTERS

4.1.1 Height of the Plant

The average height of plant recorded at 30, 60 and 90 days after sowing (DAS) is presented in Tables 2 and 3.

Different sources of organic manure caused significant variation in plant height at all growth stages. At 30 and 60 DAS, maximum plant height was recorded by banana pseudostem vermicompost treated plots (V_2) and it was on par with aquatic weed vermicompost treated plots (V_1) and significantly superior to farmyard manure (V_3). At 90 DAS, significantly superior plant height was recorded by V_2 (100.25 cm) and V_3 reported significantly inferior plant height (93.54 cm) than other organic manures.

Vermiwash application significantly influenced plant height at all growth stages. At 30 and 90 DAS, soil + foliar application of vermiwash (W_3) produced significantly superior plant height than other modes of application, followed by foliar application alone (W_2). Foliar application and soil application (W_1) were on par at early stages of plant growth (30 and 60 DAS). At later stages of plant growth (90 DAS) foliar application resulted in significantly higher plant height than soil application. Control plots *i.e.*, water spray (W_4) produced significantly lower plant height at all growth stages.

Table 2. Effect of different sources of organic manure, vermiwash and AMF on height of the plant (cm)

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	22.61	22.19	22.40	71.69	73.06	72.38	92.87	99.52	96.2
V_2	23.16	22.38	22.77	72.37	73.83	73.1	97.95	102.55	100.25
V_3	20.35	20.61	20.48	67.72	69.77	68.75	91.11	95.96	93.54
W_1	22.14	21.37	21.76	70.48	70.89	70.69	91.33	95.05	95.96
W_2	22.36	21.4	21.88	71.18	72.73	71.95	96.67	99.25	97.96
W_3	23.07	24.19	23.63	72.77	76.23	74.5	95.29	103.78	99.53
W_4	20.6	19.93	20.27	67.95	69.03	68.49	92.62	99.3	93.17
Mean	22.04	21.72		70.59	72.22		93.98	99.34	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	24.99**	23.53 **	0.57	0.51	1.33	31.50**	27..31**	9.90**	0.17	1.60	14.14**	69.5**	18.69**	2.68	11.85**
SE	0.246	0.284	0.297	0.515	0.594	0.416	0.480	0.365	0.633	0.731	0.284	0..328	0.277	0.480	0..555
CD	0.765	0.883	NS	NS	NS	1.294	1.494	1.069	NS	NS	0.885	1.022	0.812	NS	1.623

** -Significant at 1 % level
NS – Not Significant

Table 3. Interaction effect of V, W and A on height of the plant (cm)

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	22.55	22.99	22.78	71.80	71.21	71.5	89.86	90.39	90.13
$V_1 W_2$	23.15	19.85	21.48	71.74	71.96	71.85	95.02	100.02	97.52
$V_1 W_3$	23.7	26.35	25.03	72.18	78.66	75.42	94.07	106.06	100.12
$V_1 W_4$	21.05	19.6	20.33	71.07	70.41	70.74	92.55	101.52	97.03
$V_2 W_1$	22.13	19.83	20.98	71.01	72.21	71.61	93.57	101.84	97.7
$V_2 W_2$	23.25	23.3	23.28	73.60	73.56	73.58	101.29	102.23	101.76
$V_2 W_3$	25.25	25.5	25.38	74.68	77.52	76.1	99.23	105.6	102.46
$V_2 W_4$	22	20.9	21.45	70.2	72.14	71.12	97.61	100.53	99.07
$V_3 W_1$	21.75	21.3	21.53	68.64	69.26	68.95	90.57	92.94	91.75
$V_3 W_2$	20.68	21.1	20.89	68.2	72.68	70.44	93.71	95.5	94.60
$V_3 W_3$	20.25	20.73	20.49	71.45	72.51	71.98	92.48	99.57	96.03
$V_3 W_4$	18.75	19.3	19.03	62.59	64.65	63.62	87.7	95.84	91.77

	VW	VWA	VW	VWA	VW	VWA
F	7.28 **	1.27	2.74	1.73	8.24**	6.61**
SE	0.491	1.030	0.831	1.266	0.568	0.961
CD	1.529	NS	NS	NS	1.769	2.811

** - Significant at 1 % level
NS - not significant

AMF application significantly influenced plant height at 60 and 90 DAS. Maximum plant height was recorded in treated plots (A_1) compared to A_0.

The interaction effect of different sources of organic manure and vermiwash on plant height produced significant effect at 30 and 90 DAS. Banana pseudostem vermicompost along with soil + foliar application of vermiwash (V_2W_3) recorded maximum plant height at all growth stages and it was comparable with aquatic weed vermicompost along with soil + foliar application of vermiwash (V_1W_3) at 30 DAS and with V_2W_2 at 90 DAS.

VA interaction did not show any significant variation at any of the growth stages. WA interaction was significant at 90 DAS with maximum value recorded by soil + foliar application of vermiwash with AMF application i.e., W_3A_1 (103.78 cm).

VWA interaction was significant at 90 DAS with maximum plant height for banana pseudostem vermicompost along with soil + foliar application of vermiwash and AMF i.e., $V_1W_3A_1$ (106.16 cm) which was comparable with aquatic weed vermicompost along with soil + foliar application of vermiwash and AMF *i.e.*, $V_2W_3A_1$ (105.6 cm).

4.1.2 Number of Leaves Plant^{-1}

The data on number of leaves plant^{-1} is given in Table 4.

Different sources of organic manure and vermiwash caused significant influence on number of leaves plant^{-1} at all growth stages, while AMF application produced significant effect only at later growth stage (90 DAS).

Significantly higher number of leaves plant^{-1} was recorded by V_1, while V_3 recorded lowest number of leaves at all growth stages.

W_3 produced maximum number of leaves at 30 and 60 DAS, while W_2 produced maximum number of leaves at later growth stage (90 DAS).

Table 4. Effect of different sources of organic manure, vermiwash and AMF on number of leaves plant^{-1}

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	6.77	6.78	6.77	12.35	12.74	12.55	7.30	6.73	7.48
V_2	6.42	6.51	6.47	12.07	12.27	12.17	6.86	7.66	7.04
V_3	6.09	6.31	6.20	11.35	11.76	11.55	6.35	7.21	6.54
W_1	6.53	6.48	6.51	11.72	11.88	11.80	6.68	7.13	6.91
W_2	6.82	6.76	6.79	11.98	12.51	12.24	7.39	7.66	7.53
W_3	6.62	7.06	6.84	12.98	13.17	13.08	7.20	7.73	7.46
W_4	5.74	5.83	5.78	11.03	11.48	11.26	6.08	6.28	6.18
Mean	6.44	6.53		11.93	12.26		6.84	7.20	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	6.51*	14.22**	0.63	0.21	0.78	12.88**	22.70**	4.04	0.17	0.31	9.34**	12.46**	4.93*	0.005	0.21
SE	0.112	0.129	0.094	0.162	0.187	0.140	0.161	0.117	0.203	0.234	0.154	0.177	0.307	0.116	0.200
CD	0.347	0.401	NS	NS	NS	0.435	0.502	NS	NS	NS	0.478	0.552	0.339	NS	NS

* - Significant at 5 % level ** - Significant at 1 % level
NS – not significant

AMF application produced significant variation only at 90 DAS with maximum number of leaves in A_1.

Interaction effect of V, W and A was not significant.

4.1.3 Leaf Area Index (LAI)

The effect on LAI and its interaction is given in Tables 5 and 6.

Different sources of organic manure showed significant influence on LAI of plant. V_1 produced maximum leaf area index at all growth stages, which was on par with V_2, while V_3 recorded significantly lower leaf area index.

Vermiwash application caused significant effect on leaf area index with maximum leaf area index shown by W_3, while control treatment (W_4) produced significantly lower leaf area index.

AMF application significantly influenced leaf area index only at 60 DAS with maximum leaf area index in A_1.

The interaction effect of VW had significant influence on leaf area index only at 30 DAS. V_1W_3 produced the maximum value of leaf area index (0.752), while lowest leaf area index was shown by V_3W_4 (0.397).

W_3A_1 recorded significantly higher leaf area index than other treatments at 60 and 90 DAS.

Interaction effect of VA and VWA was not significant at all growth stages.

4.1.4 Number of Branches Plant^{-1}

The data on number of branches plant^{-1} is presented in Table 7. There was no significant difference on number of branches plant^{-1} with different sources of organic manure, vermiwash and AMF.

4.1.5 Dry Matter Production

The dry matter production recorded at 30, 60 and 90 DAS is presented in Tables 8 and 9.

Table 5. Effect of different sources of organic manure, vermiwash and AMF on leaf area index

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	0.576	0.658	0.617	1.059	1.091	1.075	0.729	0.748	0.739
V_2	0.600	0.631	0.615	1.037	0.991	1.014	0.699	0.703	0.701
V_3	0.528	0.538	0.533	0.949	1.123	0.970	0.610	0.606	0.608
W_1	0.540	0.624	0.582	0.972	1.002	0.987	0.684	0.722	0.703
W_2	0.581	0.577	0.579	0.999	1.073	1.036	0.707	0.651	0.679
W_3	0.620	0.727	0.674	1.088	1.243	1.166	0.722	0.788	0.755
W_4	0.530	0.511	0.521	1.002	0.955	0.979	0.605	0.582	0.593
Mean	0.568	0.609		1.015	1.068		0.679	0.686	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	7.61**	9.73**	4.18	1.10	2.39	11.1**	16.11**	6.33*	0.60	4.02*	23.07**	17.35**	0.25	0.29	4.68*
SE	0.018	0.020	0.014	0.025	0.029	0.019	0.022	0.015	0.026	0.03	0.014	0.016	0.009	0.016	0.018
CD	0.055	0.063	NS	NS	NS	0.058	0.067	0.044	NS	0.087	0.044	0.050	NS	NS	0.053

** - Significant at 1 % level   * - Significant at 5 % level
NS - not significant

Table 6. Interaction effect of V, W and A on leaf area index

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	0.480	0.614	0.547	1.032	0.953	0.992	0.729	0.732	0.730
$V_1 W_2$	0.567	0.623	0.599	1.071	1.072	1.071	0.728	0.720	0.725
$V_1 W_3$	0.650	0.855	0.752	1.131	1.388	1.260	0.781	0.901	0.841
$V_1 W_4$	0.609	0.533	0.571	1.003	0.954	0.978	0.677	0.640	0.659
$V_2 W_1$	0.616	0.652	0.634	0.967	1.098	1.030	0.674	0.720	0.697
$V_2 W_2$	0.636	0.559	0.547	1.011	1.111	1.060	0.692	0.682	0.687
$V_2 W_3$	0.634	0.746	0.690	1.105	1.267	1.186	0.760	0.809	0.785
$V_2 W_4$	0.613	0.578	0.595	1.067	1.015	1.040	0.670	0.603	0.636
$V_3 W_1$	0.523	0.606	0.564	0.917	0.954	0.935	0.648	0.714	0.681
$V_3 W_2$	0.641	0.541	0.591	0.916	1.037	0.976	0.700	0.552	0.626
$V_3 W_3$	0.579	0.581	0.580	1.029	1.075	1.051	0.624	0.655	0.640
$V_3 W_4$	0.371	0.423	0.395	0.937	0.898	0.917	0.469	0.503	0.481

	VW	VWA	VW	VWA	VW	VWA
F	3.47*	1.27	1.10	1.46	1.98	1.97
SE	0.035	0.050	0.037	0.052	0.028	0.032
CD	0.109	NS	NS	NS	NS	NS

* - Significant at 5 % level NS- not Significant

Table 7. Effect of different sources of organic manure, vermiwash and AMF on number of branches plant^{-1}

Treatments	A_0	A_1	Mean
V_1	1.78	1.70	1.74
V_2	1.50	1.57	1.54
V_3	1.40	1.60	1.50
W_1	1.51	1.37	1.44
W_2	1.64	1.93	1.78
W_3	1.57	1.88	1.73
W_4	1.53	1.31	1.42
Mean	1.56	1.62	

	V	W	A	VA	WA
F	1.67	2.69	0.37	0.66	1.96
SE	0.100	0.115	0.070	0.121	0.140
CD	NS	NS	NS	NS	NS

NS – Not significant

Table 8. Effect of different sources of organic manure, vermiwash and AMF on dry matter production (kg ha^{-1})

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	208.86	218.48	213.67	885.73	960.71	923.22	1526.56	1616.99	1571.78
V_2	205.59	211.97	208.78	861.85	928.79	895.32	1502.17	1569.23	1535.70
V_3	186.82	192.31	189.57	835.49	901.45	868.47	1475.94	1542.96	1509.45
W_1	195.05	201.41	198.23	814.62	876.90	845.76	1454.10	1517.40	1486.20
W_2	198.76	208.69	203.72	938.12	1020.91	979.51	1578.84	1659.12	1618.98
W_3	204.66	213.86	209.26	961.15	1045.13	1003.14	1601.57	1708.71	1655.14
W_4	203.21	206.39	204.80	730.21	778.32	754.27	1370.83	1420.34	1395.59
Mean	200.42	207.59		861.02	930.32		1501.56	1576.39	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	11.01**	1.05	4.07	0.13	0.19	149.90**	205.33**	443.50**	0.75	6.91**	96.15**	106.17**	359.19**	3.89*	9.93**
SE	3.839	4.433	2.512	4.351	5.024	2.236	2.582	2.327	4.030	4.653	3.191	3.685	2.792	4.836	5.585
CD	11.950	NS	NS	NS	NS	6.960	8.037	6.808	NS	13.615	9.932	11.469	8.170	14.152	16.341

** Significant at 1 % level * Significant at 5 % level
NS - Not significant

Table 9. Interaction effect of V, W and A on dry matter production (kg ha^{-1})

Treatments	30 DAS			60 DAS			90 DAS		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	206.53	215.54	211.03	823.65	897.24	860.44	1464.31	1537.62	1500.96
$V_1 W_2$	211.56	224.79	217.50	977.74	1041.30	1009.52	1618.47	1675.11	1646.79
$V_1 W_3$	209.22	223.44	217.01	997.37	1110.21	1053.79	1637.90	1820.19	1729.05
$V_1 W_4$	208.12	210.17	209.14	744.17	794.11	769.14	1385.57	1435.05	1410.31
$V_2 W_1$	196.56	201.11	198.83	813.55	885.04	849.30	1453.53	1525.49	1489.51
$V_2 W_2$	206.07	214.56	210.32	939.05	1021.43	980.24	1579.88	1661.82	1620.85
$V_2 W_3$	210.16	216.82	213.49	968.46	1027.59	998.02	1608.69	1667.89	1638.29
$V_2 W_4$	209.57	215.40	212.48	726.36	781.12	753.74	1366.60	1421.72	1394.16
$V_3 W_1$	182.08	187.59	184.83	806.65	848.43	827.54	1447.16	1489.10	1468.13
$V_3 W_2$	178.64	188.08	183.36	897.57	1000.02	948.79	1538.17	1640.44	1589.31
$V_3 W_3$	194.61	199.98	197.29	917.63	997.61	957.62	1558.13	1638.06	1598.09
$V_3 W_4$	191.96	193.60	192.78	720.12	759.73	739.93	1360.33	1404.26	1382.29

	VW	VWA	VW	VWA	VW	VWA
F	0.385	0.057	12.492**	3.566**	15.469**	7.987**
SE	7.679	8.702	4.472	8.060	6.382	9.673
CD	NS	NS	13.920	23.582	19.865	28.303

** Significant at 1 % level
NS- Not Significant

Different sources of organic manure showed significant variation in dry matter production at all growth stages. V_1 recorded higher dry matter production while V_3 recorded lower dry matter production at all growth stages. Vermiwash application also significantly influenced dry matter production at 60 and 90 DAS. W_3 recorded maximum dry matter production than other methods of application, which was on par with W_2 and W_1 both at 60 and 90 DAS. The lowest dry matter production was recorded by W_4.

AMF application significantly influenced dry matter production at 60 and 90 DAS with the highest value for A_1

The interaction effect of VW had significant influence on dry matter production at 60 and 90 DAS. V_1W_3 recorded higher dry matter production of 1053.79 kg ha^{-1} at 60 DAS and 1729.05 kg ha^{-1} at 90 DAS.

V_2A_1 recorded higher dry matter production at 60 and 90 DAS. W_3A_1 recorded significantly higher dry matter production than other treatments at 60 and 90 DAS.

The interaction effect of VWA was significant both at 60 and 90 DAS with $V_1W_3A_1$ recording significantly higher dry matter production than other treatment combinations, while $V_3W_4A_0$ recording lower dry matter production.

4.2 ROOT CHARACTERISTICS

4.2.1 Root Spread

The data on root spread is presented in Table 10. Different sources of organic manures and AMF and their interactions did not significantly influenced root spread.

Vermiwash showed significant variation in root spread. Root spread was higher for W_3 (28.51 cm) which was on par with W_1. Control treatment (W_4) showed least value (25.68 cm).

Interaction effect of V, W and A was not significant.

Table 10. Effect of different sources of organic manure, vermiwash and AMF on root characteristics of bhindi

Treatments	Root spread (cm)			Tap root length (cm)			Root shoot ratio		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	27.26	27.80	27.53	17.01	17.91	17.46	0.22	0.23	0.23
V_2	26.84	27.11	26.98	17.49	17.96	17.73	0.21	0.21	0.21
V_3	25.98	26.19	26.08	15.09	16.35	15.72	0.18	0.23	0.21
W_1	27.71	26.28	27.00	16.53	17.80	17.17	0.20	0.23	0.21
W_2	26.01	26.50	26.26	16.02	16.48	16.25	0.21	0.23	0.22
W_3	27.77	29.25	28.51	17.67	18.77	18.22	0.21	0.24	0.22
W_4	25.26	26.10	25.68	15.90	16.58	16.24	0.20	0.20	0.20
Mean	26.69	27.03		16.52	17.41		0.20	0.23	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	2.78	5.81*	0.32	0.03	1.08	20.18**	11.21**	11.47**	0.77	0.50	0.98	0.92	4.74	1.27	0.44
SE	0.439	0.507	0.427	0.740	0.855	0.243	0.280	0.184	0.318	0.367	0.010	0.011	0.008	0.013	0.015
CD	NS	1.578	NS	NS	NS	0.756	0.873	0.537	NS	NS	NS	NS	0.023	NS	NS

** Significant at 1 % level * Significant at 5 % level
NS - Not significant

4.2.2 Length of Taproot

The data on taproot length is given in Table 10. Taproot length varied significantly among different sources of organic manure, mode of vermiwash application and AMF application. Superior taproot length was noticed for V_2 and more or less same taproot length was observed for V_1. The lowest taproot length was produced by plants applied with V_3.

W_3 showed significantly higher taproot length (18.22 cm) than other modes of application which were on par.

A_1 showed higher taproot length (17.41 cm) than A_0.

Interaction between sources of organic manure, vermiwash and AMF was not significant.

4.2.3 Root Shoot Ratio

The root shoot ratio is presented in table 10.

Vermicompost, farmyard manure, vermiwash and their interactions could not significantly influence the root shoot ratio of bhindi.

The plots treated with AMF significantly influenced root shoot ratio of plant with a root shoot ratio of 0.23 in A_1 compared to A_0 with 0.20.

Interaction effect of V W and A was not significant.

4.2.4 Root Colonization percent of AMF

The average root colonization percentage of AMF at 30,45,60,75 and 90 DAS are presented in Table 11.

Of the different sources of organic manures and modes of application of vermiwash, V_1W_3 recorded higher colonization of AMF, at all growth stages. V_1W_3 recorded higher colonization percentage of 86.28 at 30 DAS, 88.98 at 45 DAS, 90.25 at 60DAS, 90.66 at 75 DAS and 92 at 90 DAS.

Table 11 Root colonization percentage of AMF

Treatment combinations	30 DAS		45 DAS		60 DAS		75 DAS		90 DAS	
	A_0	A_1	A_0	A_1	A_0	A_1	A_0	A_1	A_0	A_1
V_1 W_1	50.24	80.42	52.28	84.00	53.32	85.00	53.00	86.62	54.44	87.00
V_1 W_2	60.54	82.00	64.46	85.62	64.48	88.65	65.22	88.75	66.00	89.85
V_1 W_3	60.86	86.28	64.22	88.98	65.62	90.25	65.85	90.66	65.98	92.00
V_1 W_4	48.00	80.34	52.00	81.28	55.00	83.36	56.62	84.00	57.00	85.54
V_2 W_1	62.00	85.65	66.00	85.62	67.61	86.00	68.00	87.74	67.00	88.00
V_2 W_2	60.24	84.24	63.36	86.00	64.00	87.59	65.44	88.65	66.32	89.04
V_2 W_3	64.33	85.04	68.86	87.65	69.92	88.89	70.02	89.00	72.00	90.21
V_2 W_4	65.44	82.00	67.00	84.23	68.85	85.78	69.00	86.00	70.22	87.02
V_3 W_1	48.62	80.68	52.26	84.63	53.00	87.65	54.47	88.00	55.98	89.00
V_3 W_2	49.49	82.49	56.64	85.00	58.86	87.00	59.00	88.88	60.00	89.05
V_3 W_3	52.62	84.64	52.00	84.24	54.46	87.90	55.00	89.12	56.68	90.55
V_3 W_4	45.64	78.64	50.33	82.26	52.29	83.94	53.07	84.00	54.00	85.04

Data statistically not analyzed

4.3 YIELD ATTRIBUTES

4.3.1 Days for 50 per cent Flowering

The mean number of days taken for 50 per cent flowering is given in Table 12.

The influence of different sources of organic manure on number of days taken for 50 per cent flowering was found to be significant. Number of days taken for 50 per cent flowering was significantly delayed with $V_3$and V_2 (40 days) while those supplied with V_1 took only 38 days.

Vermiwash, AMF and their interactions did not produce any significant influence on the days for 50 per cent flowering.

4.3.2 Number of Flowers Plant^{-1}

The average number of flowers plant^{-1} produced is given in Tables 13 and 14.

Different sources of organic manure influenced number of flowers plant^{-1}. V_1 produced maximum number of flowers (15.43) compared to V_2 (12.88) and V_3 (12.80) which were on par.

Vermiwash. AMF and their interactions did not significantly influence the number of flowers produced plant^{-1}. .

4.3.3 Number of Fruits Plant^{-1}

The average number of fruits produced plant^{-1} is given in Table 13 and 14.

Different sources of organic manure recorded significant influence on number of fruits plant^{-1}. V_1 registered highest number of fruits plant^{-1} (13.87). while V_2 (11.36) and V_3 (11.16) recorded more or less same number of fruits plant^{-1}.

No significant difference was observed with respect to vermiwash application and AMF.

Table 12. Effect of different sources of organic manure, vermiwash and AMF on days for 50 per cent flowering

Treatments	A_0	A_1	Mean
V_1	38.25	38.50	38.38
V_2	39.75	39.25	39.50
V_3	39.88	40.63	40.25
W_1	38.50	39.50	39.00
W_2	39.50	39.67	39.58
W_3	39.50	39.00	39.25
W_4	39.67	39.67	39.67
Mean	39.29	39.45	39.38

	V	W	A	VA	WA
F	5.67*	0.45	0.11	0.52	0.39
SE	0.396	0.458	0.355	0.615	0.711
CD	1.234	NS	NS	NS	NS

* Significant at 5 % level, NS – Not significant

Table 13. Effect of different sources of organic manure, vermiwash and AMF on number of flowers plant $^{-1}$, number of fruits plant $^{-1}$ and setting percentage of bhindi

Treatments	Number of flowers plant $^{-1}$			Number of fruits plant $^{-1}$			Setting percentage		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	15.30	15.56	15.43	13.65	14.09	13.87	89.52	90.22	89.87
V_2	12.48	13.28	12.88	11.16	11.55	11.36	89.52	86.82	88.17
V_3	12.91	12.69	12.80	10.93	11.40	11.16	84.74	89.59	87.17
W_1	12.80	13.03	12.92	11.00	11.68	11.38	86.16	89.66	87.91
W_2	13.57	14.48	14.03	11.98	12.88	12.43	88.35	88.69	88.52
W_3	14.87	14.80	14.83	13.32	13.42	13.37	89.28	90.41	89.85
W_4	13.02	13.05	13.03	11.35	11.40	11.34	87.90	86.75	87.33
Mean	13.56	13.84		11.91	12.35		87.88	88.92	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	4.91*	1.34	0.18	0.20	0.11	5.20*	1.60	0.50	0.002	0.12	1.41	0.66	0.56	2.96	0.59
SE	0.676	0.781	0.0467	0.809	0.934	0.662	0.765	0.435	0.753	0.870	1.151	1.329	0.897	1.554	1.794
CD	2.105	NS	NS	NS	NS	2.062	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Significant at 5 % level, NS - Not significant

Table 14. Interaction effect of V, W and A on number of flowers plant $^{-1}$, number of fruits plant $^{-1}$ and setting percentage of bhindi

Treatments	Number of flowers plant $^{-1}$			Number of fruits plant $^{-1}$			Setting percentage		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	15.60	15.00	15.30	13.05	13.55	13.30	83.99	90.57	87.28
$V_1 W_2$	14.60	15.80	15.20	13.35	14.25	13.80	91.44	89.97	90.71
$V_1 W_3$	16.60	16.45	16.53	15.35	15.10	15.23	92.26	91.67	91.96
$V_1 W_4$	14.40	15.00	14.70	12.85	13.45	13.15	90.39	88.69	89.54
$V_2 W_1$	11.10	12.20	11.65	9.75	10.95	10.35	89.57	89.95	88.76
$V_2 W_2$	13.20	14.15	13.68	11.95	12.35	12.15	91.11	87.15	89.13
$V_2 W_3$	13.45	14.20	13.83	12.20	12.65	12.43	90.58	88.87	89.72
$V_2 W_4$	12.15	12.55	12.35	10.75	10.25	10.50	88.81	81.33	85.07
$V_3 W_1$	11.70	11.90	11.80	10.20	10.55	10.38	86.93	88.48	87.70
$V_3 W_2$	12.90	13.50	13.20	10.65	12.05	11.35	82.51	88.95	85.73
$V_3 W_3$	14.55	13.75	14.15	12.40	12.50	12.45	85.01	90.71	87.86
$V_3 W_4$	12.50	11.60	12.05	10.45	10.50	10.48	84.51	90.24	87.37

	VW	VWA	VW	VWA	VW	VWA
F	0.12	0.07	0.05	0.06	0.55	0.68
SE	1.353	1.617	1.325	1.506	2.301	3.107
CD	NS	NS	NS	NS	NS	NS

NS - Not Significant

V_1W_3 recorded maximum number of fruits and V_3W_1 recorded lowest number of fruits $plant^{-1}$. V_1A_0 and V_1A_1 recorded maximum number of fruits $plant^{-1}$. WA interaction was not significant. $V_1W_3A_1$ recorded higher number of fruits $plant^{-1}$ compared to other combinations.

4.3.4 Setting Percentage

The data on percentage of fruit set are presented in Table 13 and 14. Different sources of vermicompost, vermiwash and AMF could not significantly influence the percentage of fruit set.

4.3.5 Height of the First Bearing Node

The data on height of the first bearing node is presented in Table 15. Either different sources of organic manure or vermiwash or AMF showed any significant influence on height of first bearing node.

4.3.6 Length and Girth of the Fruit

The data on mean length and girth of fruits are presented in Table 16 and 17. There was no significant difference observed on length and girth of fruits when different sources of vermicompost, vermiwash and AMF were applied. The length of fruit varied from 16.88 cm in $V_1W_3A_1$ to 16.02 cm in $V_3W_4A_0$ and the girth varied from 5.63 cm in $V_1W_3A_1$ to 5.11 cm in $V_3W_1A_0$.

4.3.7 Fruit Yield $Plant^{-1}$

The data on fruit yield produced $plant^{-1}$ (g $plant^{-1}$) is presented in Table 18 and 19.

Different sources of organic manure could significantly influence the fruit yield $plant^{-1}$. An increased fruit yield of 287.76 g $plant^{-1}$ was recorded with V_1 followed by V_2 (186.79 g $plant^{-1}$) which was comparable with V_3 (181.67 g $plant^{-1}$).

Vermiwash and AMF and their interactions did not produce any significant influence on fruit yield $plant^{-1}$.

Table 15. Effect of different sources of organic manure, vermiwash and AMF on height (cm) of first bearing node

Treatments	A_0	A_1	Mean
V_1	20.12	20.29	20.20
V_2	20.48	19.87	20.17
V_3	19.34	19.42	19.38
W_1	19.95	19.98	19.97
W_2	20.39	20.13	20.26
W_3	20.27	20.31	20.29
W_4	19.31	18.99	19.15
Mean	19.98	19.86	

	V	W	A	VA	WA
F	3.41	3.29	0.14	0.54	0.07
SE	0.253	0.293	0.238	0.411	0.475
CD	NS	NS	NS	NS	NS

NS – Not significant

Table 16. Effect of different sources of organic manure ,vermiwash and AMF on length and girth of the fruit of bhindi

Treatments	Length of the fruit (cm)			Girth of the fruit (cm)		
	A_0	A_1	Mean	A_0	A_1	Mean
V_1	16.56	16.39	16.48	5.62	5.44	5.53
V_2	16.52	16.31	16.41	5.52	5.26	5.39
V_3	16.42	16.51	16.46	5.50	5.54	5.52
W_1	16.32	16.49	16.41	5.57	5.43	5.50
W_2	16.60	16.30	16.45	5.65	5.28	5.47
W_3	16.66	16.39	16.53	5.51	5.42	5.47
W_4	16.41	16.42	16.42	5.45	5.55	5.50
Mean	16.50	16.40		5.54	5.42	

	V	W	A	VA	WA	V	W	A	VA	WA
F	0.04	0.09	0.37	0.34	0.49	0.49	0.02	0.55	0.36	0.32
SE	0.161	0.186	0.114	0.197	0.228	0.118	0.137	0.118	0.205	0.236
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 17. Interaction effect of V, W and A on length and girth of the fruit of bhindi

Treatments	Length of the fruit (cm)			Girth of the fruit (cm)		
	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	16.33	16.30	16.32	5.32	5.39	5.36
$V_1 W_2$	16.10	16.60	16.35	5.40	5.34	5.37
$V_1 W_3$	16.55	16.88	16.72	5.48	5.63	5.56
$V_1 W_4$	16.35	16.30	16.33	5.29	5.40	5.35
$V_2 W_1$	16.19	16.31	16.25	5.15	5.34	5.25
$V_2 W_2$	16.18	16.30	16.24	5.32	5.47	5.37
$V_2 W_3$	16.28	16.42	16.35	5.40	5.53	5.40
$V_2 W_4$	16.17	16.32	16.25	5.13	5.36	5.25
$V_3 W_1$	16.15	16.26	16.21	5.11	5.32	5.22
$V_3 W_2$	16.51	16.63	16.57	5.33	5.20	5.27
$V_3 W_3$	16.24	16.32	16.28	5.38	5.44	5.41
$V_3 W_4$	16.02	16.25	16.14	5.13	5.28	5.21

	VW	VWA	VW	VWA
F	0.34	0.08	0.32	0.29
SE	0.322	0.394	0.237	0.410
CD	NS	NS	NS	NS

NS - Not significant

Table 18. Effect of different sources of organic manure, vermiwash and AMF on fruit yield plant $^{-1}$ and total fruit yield of bhindi

Treatments	Fruit yield plant $^{-1}$ (g plant^{-1})			Total fruit yield (q ha^{-1})		
	A_0	A_1	Mean	A_0	A_1	Mean
V_1	285.34	219.17	287.75	106.31	108.11	107.21
V_2	185.09	188.48	186.79	69.17	70.43	69.80
V_3	179.29	184.05	181.67	67.02	68.82	67.92
W_1	194.13	198.17	196.15	72.53	74.02	73.27
W_2	225.27	238.38	231.82	84.04	88.98	86.51
W_3	253.61	254.95	254.28	94.55	95.05	94.80
W_4	193.29	192.10	192.69	72.22	71.77	71.99
Mean	216.57	220.90		60.55	59.51	

	V	W	A	VA	WA	V	W	A	VA	WA
F	19.28**	3.53	0.11	0.001	0.06	19.25**	3.53	0.11	0.001	0.06
SE	13.625	15.733	9.308	16.121	18.615	5.051	5.832	3.449	5.979	6.898
CD	42.410	NS	NS	NS	NS	15.714	NS	NS	NS	NS

Table 19. Interaction effect of V, W and A on fruit yield plant^{-1} and total fruit yield of bhindi

Treatments	Fruit yield plant^{-1} (g plant^{-1})			Total fruit yield (q ha^{-1})		
	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	268.99	268.64	268.82	100.25	100.12	100.19
$V_1 W_2$	285.03	296.95	290.99	106.20	110.70	108.45
$V_1 W_3$	336.07	329.07	332.57	125.10	122.50	123.80
$V_1 W_4$	251.28	266.00	258.64	93.70	99.13	96.41
$V_2 W_1$	151.61	166.88	259.24	56.78	62.43	59.60
$V_2 W_2$	209.66	207.98	208.82	78.22	77.66	77.94
$V_2 W_3$	216.68	226.64	221.66	80.88	84.57	82.72
$V_2 W_4$	162.43	152.43	157.43	60.79	57.08	58.93
$V_3 W_1$	161.80	158.98	160.39	60.55	59.51	60.03
$V_3 W_2$	181.12	210.21	195.66	67.69	78.59	73.14
$V_3 W_3$	208.08	209.14	208.61	77.69	78.08	77.89
$V_3 W_4$	166.16	157.87	162.02	62.17	59.10	60.63

	VW	VWA	VW	VWA
F	0.099	0.095	0.098	0.095
SE	27.250	32.243	10.102	11.949
CD	NS	NS	NS	NS

* Significant at 5 % level, ** Significant at 1% level NS not significant

4.3.8 Total Fruit Yield

The data on total fruit yield (q ha^{-1}) is given in Table 18 and 19.

Different sources of organic manure recorded significant influence on total fruit yield. V_1 produced maximum significantly higher fruit yield of 107.21 q ha^{-1} while V_3 produced lowest fruit yield of 67.92 q ha^{-1}.

Vermiwash and AMF and their interactions did not produce any significant influence on total fruit yield.

4.3.9 Number of Seeds $Fruit^{-1}$

The data on mean number of seeds $fruit^{-1}$shown is given in Table 20 and 21.

Different sources of organic manure significantly influenced the number of seeds produced $fruit^{-1}$ V_1 registered maximum number of seeds $fruit^{-1}$ (54.18) followed by V_2 (50.44) and it was on par with V_3 (49.81).

Vermiwash produced significant influence on number of seeds per fruit. W_3 produced higher number of seeds $fruit^{-1}$which was on par with W_2. W_1 produced least number of seeds $fruit^{-1}$

VW interaction significantly influenced number of seeds produced $fruit^{-1}$. V_1W_3 recorded maximum number of seeds per fruit (61.85) which was on par with V_1W_2 (61.33).

WA and VA did not produce significant effect on number of seeds per fruit.

VWA interaction was significant with number of seeds produced $fruit^{-1}$ $V_1W_3A_1$ (65.10) produced the maximum value and was on par with $V_1W_2A_1$ (61.18) and $V_1W_3A_0$ (60.60).

4.3.10 Weight of Seeds $Fruit^{-1}$

Mean weight of seeds per fruit is presented in Tables 20 and 21.

Different sources of organic manure could not significantly influence weight of seeds $fruit^{-1}$.

Table 20. Effect of different sources of organic manure ,vermiwash and AMF on number of seeds plant^{-1} and weight of seeds plant^{-1} of bhindi

Treatments	Number of seeds fruit^{-1}			Weight of seeds fruit^{-1} (g)		
	A_0	A_1	Mean	A_0	A_1	Mean
V_1	53.54	54.81	54.18	2.75	3.15	2.95
V_2	50.75	50.13	50.44	2.63	2.91	2.77
V_3	49.69	49.94	49.81	2.49	2.92	2.70
W_1	45.82	47.08	46.45	2.24	2.74	2.49
W_2	55.62	56.22	55.92	3.12	3.59	3.36
W_3	55.92	56.90	56.41	3.27	3.66	3.47
W_4	47.95	46.30	47.13	1.86	1.97	1.91
Mean	51.33	51.63		2.62	2.99	

	V	W	A	VA	WA	V	W	A	VA	WA
F	7.04*	27.89**	0.10	0.31	0.45	2.19	55.03**	7.80*	0.11	0.46
SE	0.889	1.027	0.697	1.208	1.395	0.086	0.100	0.093	0.161	0.186
CD	2.768	3.197	NS	NS	NS	NS	0.310	0.273	NS	NS

Table 21. Interaction effect of V, W and A on number of seeds plant^{-1} and weight of seeds plant^{-1} of bhindi

Treatments	Number of seeds fruit^{-1}			Weight of seeds fruit^{-1} (g)		
	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	47.55	46.40	46.98	2.30	2.79	2.54
$V_1 W_2$	57.55	61.18	59.37	3.37	3.75	3.56
$V_1 W_3$	60.60	65.10	62.85	3.43	3.93	3.68
$V_1 W_4$	46.45	46.65	46.55	1.91	2.13	2.02
$V_2 W_1$	43.35	47.10	45.23	2.24	2.76	2.50
$V_2 W_2$	60.80	52.85	56.83	3.15	3.55	3.35
$V_2 W_3$	49.30	55.50	52.40	3.28	3.53	3.40
$V_2 W_4$	49.55	45.05	47.30	1.86	1.82	1.84
$V_3 W_1$	46.55	47.75	47.15	2.17	2.68	2.42
$V_3 W_2$	48.50	50.70	49.60	2.86	3.49	3.17
$V_3 W_3$	55.85	54.10	54.98	3.11	3.53	3.32
$V_3 W_4$	47.85	47.20	47.53	1.81	1.96	1.88

	VW	VWA	VW	VWA
F	4.001*	2.602*	0.21	0.05
SE	1.779	2.415	0.173	0.323
CD	5.537	7.067	NS	NS

* Significant at 5 % per cent ** Significant at1 % level, NS - Not significant

Vermiwash application significantly influenced weight of seeds $fruit^{-1}$ with maximum weight of seeds $fruit^{-1}$ in W_3 (3.47 g) followed by W_2 (3.36 g).

AMF application significantly influenced weight of seeds per fruit with 2.99 g $fruit^{-1}$ in A_1.

Interaction effect of V, W and A was not significant.

4.3.11 Seed Yield

The data on seed yield (kg ha^{-1}) is presented in Tables 22 and 23.

Different sources of organic manure, vermiwash and AMF produced significant influence on seed yield ha^{-1}.

V_1 produced significantly higher seed yield (459.36 kg ha^{-1}) followed by V_2 (385.79 kg ha^{-1}) and V_3 (369.40 kg ha^{-1}).

W_3 produced significantly superior seed yield (493.70 kg ha^{1}) which was on par with W_2 (463.86 kg ha^{-1}). W_4 recorded the lowest seed yield of 288.44 kg ha^{-1}.

AMF application produced significant effect on seed yield with maximum seed yield of 415.21 kg ha^{-1} in A_1.

Interaction effect of V, W and A was not significant.

4.4 QUALITY ASPECTS OF SEED

4.4.1 Seed Viability

The data on seed viability is given in Table 24.

Either different sources of organic manure, vermiwash or AMF caused no significant influence on seed viability.

4.4.2 Vigour Index

The data on vigour index is presented in Table 24.

Different sources of organic manure and vermiwash produced no significant influence in seedling vigour.

Table 22. Effect of different sources of organic manure, vermiwash and AMF on seed yield (kg ha^{-1}) of bhindi

Treatments	A_0	A_1	Mean
V_1	448.32	470.40	459.36
V_2	378.65	392.92	385.79
V_3	346.51	392.30	369.40
W_1	345.13	353.67	349.40
W_2	435.93	491.79	463.86
W_3	469.43	570.97	493.70
W_4	279.50	297.39	288.44
Mean	382.49	415.21	

	V	W	A	VA	WA
F	35.31**	89.53**	11.42**	0.52	1.42
SE	8.820	10.184	6.845	11.856	13.690
CD	27.452	31.699	20.028	NS	NS

Table 23. Interaction effect of V, W and A on seed yield (kg ha^{-1}) of bhindi

Treatments	A_0	A_1	Mean
$V_1 W_1$	398.48	404.68	401.58
$V_1 W_2$	496.98	545.09	521.03
$V_1 W_3$	578.32	585.79	582.05
$V_1 W_4$	319.49	346.07	332.78
$V_2 W_1$	308.85	320.96	314.91
$V_2 W_2$	406.93	452.78	429.85
$V_2 W_3$	429.39	494.88	462.13
$V_2 W_4$	265.45	263.05	264.25
$V_3 W_1$	328.07	335.37	331.72
$V_3 W_2$	403.87	477.51	440.69
$V_3 W_3$	400.57	473.25	436.91
$V_3 W_4$	253.55	283.06	268.30

	VW	VW A
F	1.777	0.373
SE	17.639	23.711
CD	NS	NS

** Significant at 1 per cent level   NS – Not significant

Table 24. Effect of different sources of organic manure , vermiwash and AMF on quality aspects of seed

Treatments	Seed viability			Vigour index			Germination percentage		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	91.88	90.63	91.25	1803.13	1820.19	1811.66	88.18	89.68	88.95
V_2	88.13	88.13	88.13	1761.94	1810.50	1786.22	88.13	89.38	88.75
V_3	87.50	84.38	85.94	1603.06	1647.69	1625.38	85.00	85.63	85.31
W_1	90.00	87.50	88.75	1714.58	1663.67	1689.13	85.83	86.66	86.25
W_2	89.17	87.50	88.33	1758.33	1784.75	1771.54	89.16	89.16	89.16
W_3	90.83	92.50	91.67	1794.25	2014.33	1904.29	88.33	93.33	90.83
W_4	86.67	83.33	85.00	1623.67	1575.08	1599.38	85.00	83.33	84.16
Mean	89.17	87.71		1722.71	1759.46		87.08	88.13	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	2.21	1.73	0.50	0.19	0.28	6.20*	7.65**	0.89	0.06	2.66	2.37	3.98*	0.45	0.02	0.84
SE	1.797	2.075	1.459	2.526	2.917	40.575	46.852	27.632	47.859	55.263	1.291	1.490	1.095	1.897	2.190
CD	NS	NS	NS	NS	NS	126.298	145.837	NS	NS	NS	NS	4.639	NS	NS	NS

* Significant at 5 % level, ** Significant 1 per cent level, NS - Not significant

V_1 and V_2 showed more or less same seedling vigour. However higher seedling vigour was observed in plots treated with V_1 while lowest seedling vigour was observed in V_3.

W_3 caused significantly superior seedling vigour which was on par with W_2 while W_4 showed least seedling vigour.

AMF application did not produce any significant influence on vigour index.

Interaction effect of V, W and A was not significant.

4.4.3 Germination Percentage

The data on germination is presented in Table 24.

Either different sources of organic manure or AMF produced significant influence on germination percentage of seeds.

Vermiwash application caused significant effect on germination percentage. W_3 recorded maximum germination percentage (90.83) which was on par with W_2 (89.16) and W_1 (86.25), while W_4 recorded least germination percentage of 84.16.

Interaction effect of V, W and A was not significant.

4.5 PLANT ANALYSIS

4.5.1 Nitrogen Uptake by Plants

The average N uptake by plants is given in Table 25.

Different sources of organic manure produced significant influence on N uptake by plants, of which V_1 caused significantly higher nitrogen uptake (31.3 kg ha^{-1}) while V_3 produced significantly lower nitrogen uptake by plants (24.86 kg ha^{-1}).

Vermiwash application also recorded significant effect on nitrogen uptake by plants. Here W_3 produced significantly higher nitrogen uptake (36.29 kg ha^{-1}). W_4 caused least nitrogen uptake (20.10 kg ha^{-1}).

Table 25. Effect of different sources of organic manure, vermiwash and AMF on nutrient uptake at harvest

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	31.06	31.54	31.30	5.35	6.89	6.12	26.05	32.94	29.49
V_2	26.97	27.29	27.13	4.82	6.09	5.45	24.35	28.21	26.28
V_3	24.03	25.68	24.86	4.52	5.36	4.94	22.45	26.68	24.57
W_1	22.91	22.93	22.92	4.29	5.17	4.73	21.88	23.78	22.83
W_2	30.78	32.69	31.74	5.79	6.99	6.40	27.95	34.93	31.44
W_3	35.79	36.78	36.29	6.10	8.31	7.20	28.71	37.61	33.16
W_4	19.93	20.28	20.10	3.40	3.98	3.69	18.60	20.79	19.69
Mean	27.35	28.17		4.90	6.12		24.28	29.28	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	7.39**	29.50**	0.57	0.152	0.149	5.87*	31.79**	21.20**	0.60**	1.82**	9.38**	48.11**	38.56**	1.41	4.73*
SE	1.202	1.388	0.765	1.324	1.529	0.244	0.282	0.187	0.324	0.375	0.816	0.943	1.633	0.985	1.137
CD	3.742	4.321	NS	NS	NS	0.760	0.877	0.548	NS	NS	5.593	6.458	4.268	NS	8.536

* Significant at 5 % level, ** Significant 1 per cent level, NS - Not significant

Interaction effect of V, W and A was not significant (Table 31).

4.5.2 Phosphorus Uptake by Plants

The average P uptake by plants is given in Table 25.

Different sources of organic manure, vermiwash and AMF recorded significant influence on P uptake by plants. V_1 produced maximum P uptake (6.12 kg ha^{-1}) which was on par with V_2 (5.45 kg ha^{-1}) while V_3 recorded least P uptake (4.94 kg ha^{-1}).

W_3 registered maximum P uptake (7.20 kg ha^{-1}) which was on par with W_2 (6.40 kg ha^{-1}) while W_4 produced least P uptake (3.69 kg ha^{-1}).

AMF application caused significant effect on P uptake with maximum P uptake in A_1.

Interaction effect of V, W and A was not significant.

4.5.3 Potassium Uptake by Plants

The average K uptake by plants is given in Table 25.

Different sources of organic manure caused significant variation in K uptake by plants. Significantly higher K uptake (29.49 kg ha^{-1}) was noticed for V_1 while V_3 produced least K uptake by plants (24.57 kg ha^{-1}).

Vermiwash application registered significant influence on K uptake, of which W_3 caused maximum K uptake (33.16 kg ha^{-1}) which in turn was on par with W_2 (31.44 kg ha^{-1}). W_4 produced least K uptake (19.69 kg ha^{-1}).

AMF application also significantly influenced on K uptake with maximum K uptake in A_1 (29.28 kg ha^{-1}).

WA interaction was significant. W_3A_1 recorded maximum K uptake (37.61 kg ha^{-1}) which was on par with W_2A_1 (34.93 kg ha^{-1}).

VW, VA and VWA interaction was not significant.

4.6 SOIL ANALYSIS

4.6.1 Available Nitrogen Status

Available nitrogen status in soil after experiment is presented in Tables 26 and 27.

The organic manure addition could maintain the available nitrogen status well above the original status before the experiment. V_3 recorded significantly higher available nitrogen (293.41 kg ha^{-1}) after the experiment, which was significantly superior to V_2 (284.67 kg ha^{-1}) and V_1 (244.45 kg ha^{-1}).

W_4 recorded maximum available nitrogen status (279.22 kg ha^{-1}) than other modes of vermiwash application which were on par.

AMF application significantly influenced available nitrogen status with higher available nitrogen content (277.60 kg ha^{-1}) in A_0.

VA interaction was significant with higher available nitrogen status in V_3A_1 (293.55 kg ha^{-1}) which was on par with V_3A_0 (293.26 kg ha^{-1}). V_1A_0 and V_1A_1 recorded least available nitrogen status. VWA interaction was significant with higher available nitrogen status observed in$V_3W_1A_0$ (300.33 kg ha^{-1}) lowest with $V_1W_3A_0$ (226.58 kg ha^{-1}).

4.6.2 Available Phosphorus Status

The average soil phosphorus status is presented in Table 26 and 27.

Different sources of organic manure, vermiwash and AMF registered significant variation in available phosphorus status of soil after the experiment.

V_1 recorded significantly higher available phosphorus status (42.42 kg ha^{-1}) while V_2 and V_3 produced significantly lower available phosphorus status of soil (39.68 and 37.60 kg ha^{-1} respectively).

Vermiwash registered significantly superior available phosphorus status with W_3 recorded maximum value (52.77 kg ha^{-1}), which in turn

Table 26. Effect of different sources of organic manure, vermiwash and AMF on available nitrogen, phosphorus and potassium after the experiment

Treatments	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
V_1	247.39	241.50	244.45	37.56	47.28	42.42	105.32	118.75	112.04
V_2	292.16	277.19	284.67	36.43	42.93	39.68	111.14	124.25	117.70
V_3	293.26	293.55	293.41	34.80	40.41	37.60	102.21	115.64	108.92
W_1	274.79	272.68	273.74	29.93	41.33	35.63	100.40	105.45	102.95
W_2	282.22	272.69	277.45	48.01	54.04	51.03	114.76	137.32	126.04
W_3	273.14	259.44	266.29	48.95	56.60	52.77	121.16	142.31	131.75
W_4	280.26	278.18	279.22	18.16	22.19	20.17	88.52	93.11	90.81
Mean	277.60	270.75		36.26	43.54		106.23	119.55	

	V	W	A	VA	WA	V	W	A	VA	WA	V	W	A	VA	WA
F	137.95**	4.98*	9.08**	3.79*	1.60	9.44**	281.99**	101.80**	2.99	4.69*	109.21**	153.80**	62.99**	0.04	86.38**
SE	2.223	2.567	1.609	2.787	3.218	0.786	0.908	0.510	0.883	1.020	0.426	0.491	0.375	0.650	0.751
CD	6.921	7.991	4.709	8.156	NS	2.447	2.825	1.492	NS	4.687	1.325	1.530	1.098	NS	2.196

* Significant at 5 % level. ** Significant at 1 per cent level. NS - Not significant

Table 27. Interaction effect of V, W and A on available nitrogen, phosphorus and potassium after the experiment

Treatments	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	A_0	A_1	Mean	A_0	A_1	Mean	A_0	A_1	Mean
$V_1 W_1$	239.60	239.91	239.75	33.97	46.82	40.39	99.92	103.06	101.49
$V_1 W_2$	265.42	240.26	252.84	49.69	56.42	53.05	112.59	139.08	125.83
$V_1 W_3$	226.58	235.61	231.09	51.05	61.62	56.34	119.84	140.70	10.27
$V_1 W_4$	257.98	250.24	254.11	15.53	24.26	19.90	88.95	92.18	90.56
$V_2 W_1$	284.46	279.66	282.06	29.52	41.08	35.30	102.86	119.25	106.05
$V_2 W_2$	294.64	278.67	286.65	47.93	54.59	51.26	122.08	141.00	131.54
$V_2 W_3$	298.35	257.59	277.97	48.48	54.62	51.55	129.60	151.17	140.38
$V_2 W_4$	291.18	292.84	292.01	19.81	21.43	20.62	90.03	95.60	92.81
$V_3 W_1$	300.33	298.47	299.40	26.31	36.11	31.21	98.59	104.04	101.32
$V_3 W_2$	286.59	299.13	292.86	46.43	51.12	48.77	109.62	131.88	120.75
$V_3 W_3$	294.50	285.14	289.82	47.32	53.55	50.43	114.06	135.07	124.56
$V_3 W_4$	291.63	291.47	291.55	19.14	20.88	20.01	86.58	91.56	89.07

	VW	VWA	VW	VWA	VW	VWA
F	1.94	4.38**	1.68	0.43	11.50**	1.84
SE	4.447	5.575	1.572	1.767	0.851	1.300
CD	NS	16.311	NS	NS	2.649	NS

** Significant at 1 % level   NS - Not Significant was on par with W_2. W_4 recorded least available phosphorus status of soil (20.17 kg ha^{-1}).

AMF application also produced significant influence on available phosphorus status with maximum value for A_1 (43.54 kg ha^{-1}).

WA interaction was significant with maximum value for available phosphorus status for W_3A_1 (56.6 kg ha^{-1}) which was closely followed by W_2A_1 (54.04 kg ha^{-1}) while W_4A_0 produced the least value (18.16 kg ha^{-1}).

Interaction effect of VA, V, W and VWA was not significant.

4.6.3 Available Potassium Status

Available potassium status in soil after experiment is given in Table 26 and 27.

Different sources of organic manure caused significant variation in available potassium status of soil after the experiment. V_2 registered maximum value for available potassium status (117.7 kg ha^{-1}) while V_3 recorded least value for available potassium status (108.92 kgha^{-1}).

Vermiwash application caused significant difference in available potassium status. W_3 produced the maximum value (131.74 kg ha^{-1}) while W_4 recorded least value for available K status (90.81 kg ha^{-1}).

AMF application registered significant variation in available potassium status with maximum K status for A_1 (119.55 kg ha^{-1}).

VW interaction was significant with maximum value for V_2W_3 (140.38 kg ha^{-1}) while V_3W_4 (89.07 kg ha^{-1}) recorded the least value for available potassium status of soil.

WA interaction was also significant with W_3A_1 produced significantly higher value for available potassium status (142.31 kg ha^{-1}) while W_4A_0 recorded the least value (88.52 kg ha^{-1}).

VA and VWA interaction was not significant.

4.7 SCORING OF PEST AND DISEASES

4.7.1 Scoring of Fruit and Shoot Borer Incidence

Percentage of fruits infested by the attack of fruit and shoot borer is given in Table 28.

Different sources of organic manures and vermiwash recorded significant variation in percentage of fruits infested.

Infestation percentage of fruits was maximum in V_3 (27.46) while V_1 recorded least infestation of fruits (14.66). Vermiwash application also significantly influenced percentage of fruits infested by fruit and shoot borer. Maximum infestation of fruits in W_4 (26.54) which was on par with W_1, while W_3 registered least infestation of fruits (16.79).

Application of AMF and interaction effect of V, W and A was not significant.

4.8 ECONOMICS OF SEED PRODUCTION

4.8.1 BC Ratio

The B: C ratio is presented in Table 29 and 30. Different sources of organic manure, vermiwash and AMF produced significant difference in B: C ratio.

V_1 recorded maximum BC ratio of 2.27 while V_3 produced least BC ratio (1.86) which was on par with V_2 (1.88).

Vermiwash application also caused significant variation in BC ratio with W_3 recorded maximum value for BC ratio (2.43) which was on par with W_2 (2.32) while W_4 recorded the least value for BC ratio (1.47). AMF application also registered significant variation in BC ratio with maximum value for A_1 (2.11).

Interaction effect of V, W and A was not significant.

Table 28. Effect of different sources of organic manure, vermiwash and AMF on percentage fruits infested by fruit and shoot borer

Treatments	A_0	A_1	Mean
V_1	13.92	15.41	14.66
V_2	21.86	23.95	22.90
V_3	26.60	28.32	27.46
W_1	23.60	27.06	25.33
W_2	17.53	18.57	18.05
W_3	16.61	16.96	16.79
W_4	25.43	27.65	26.54
Mean	20.79	22.56	

	V	W	A	VA	WA
F	14.65**	6.45**	0.92	0.009	0.14
SE	1.694	1.957	1.306	2.262	2.612
CD	5.274	6.090	NS	NS	NS

** Significant at 1 per cent level NS – Not significant

Table 29. Effect of different sources of organic manure, vermiwash and AMF on BC ratio

Treatments	A_0	A_1	Mean
V_1	2.20	2.35	2.27
V_2	1.86	1.97	1.91
V_3	1.74	2.02	1.88
W_1	1.75	1.86	1.80
W_2	2.15	2.48	2.32
W_3	2.28	2.58	2.43
W_4	1.42	1.53	1.47
Mean	1.90	2.11	

	V	W	A	VA	WA
F	32.38**	89.19**	21.19**	0.76	1.73
SE	0.041	0.047	0.032	0.056	0.064
CD	0.127	0.147	0.094	NS	NS

Table 30. Interaction effect of V, W and A on BC ratio

Treatments	A_0	A_1	Mean
$V_1 W_1$	2.04	2.12	2.08
$V_1 W_2$	2.44	2.74	2.59
$V_1 W_3$	2.75	2.84	2.79
$V_1 W_4$	1.60	1.70	1.65
$V_2 W_1$	1.56	1.75	1.66
$V_2 W_2$	2.01	2.27	2.14
$V_2 W_3$	2.10	2.48	2.29
$V_2 W_4$	1.36	1.37	1.36
$V_3 W_1$	1.65	1.72	1.68
$V_3 W_2$	2.01	2.44	2.22
$V_3 W_3$	2.00	2.42	2.21
$V_3 W_4$	1.32	1.51	1.42

	VW	VWA
F	0.86	0.46
SE	0.082	0.112
CD	NS	NS

** Significant at 1 per cent level NS – Not significant

Discussion

5. DISCUSSION

An experiment was conducted to find out the effect of vermicompost, vermiwash and AMF on quality seed production of bhindi. The results obtained are discussed below.

5.1 EFFECT OF SOURCES OF ORGANIC MANURE, VERMIWASH AND THEIR INTERACTIONS ON GROWTH AND YIELD ATTRIBUTING CHARACTERS

5.1.1 Growth Characters

The crop growth parameters viz. height of the plant, leaf area index and dry matter production at various growth stages were found to be very much responsive to different sources of organic manure.

Taller plants were observed in plots applied with banana pseudostem vermicompost and it was on par with aquatic weed vermicompost at 30 and 60 DAS (Fig.3.). At maturity stage, banana pseudostem vermicompost applied plots had maximum plant height (100.25cm) than FYM (93.54cm). Increased plant height in vermicompost treated plots may be due to more proliferation of roots (Table 10) which increased more uptake of nutrients especially N, P and K. The increased uptake of nitrogen might have contributed to rapid meristamatic activity (Crowther, 1935), higher rate of metabolic activity coupled with rapid cell division brought about by phosphorus (Bear, 1965) and by increased growth of meristamatic tissue (Tisdale and Nelson, 1985). These might have led to increased plant height. Similar increase in plant height due to vermicompost application was reported in bhindi by Govindan *et al.* (1995), Ushakumari *et al.* (1999) and Shanthi and Vijayakumari (2002). Vermiwash application significantly influenced plant height at all growth stages with soil + foliar application producing maximum plant height and water spray producing least plant height (Fig. 3). The increase in plant height observed in soil + foliar application at all stages of growth could be due to increased availability of growth promoting substances from vermiwash

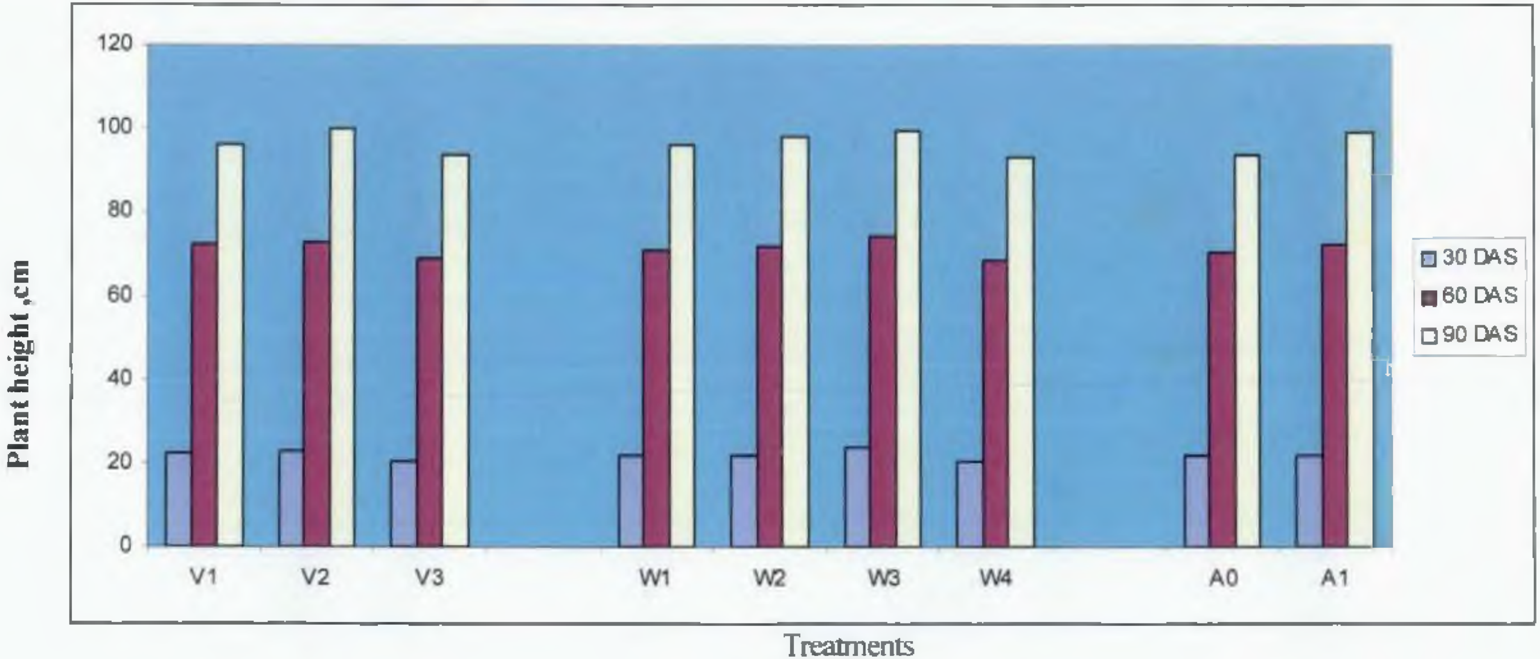


Fig. 3. Effect of different sources of organic manure, vermiwash and AMF on plant height (cm)

through soil and foliage than other modes of application. Different sources of organic manure along with vermiwash application produced significant influence on plant height at early and later stages of growth (Table 3). Soil + foliar application of vermiwash with banana pseudostem vermicompost (V_2W_3) recorded maximum plant height at all growth stages. Increase in plant height when banana pseudostem vermicompost applied with soil + foliar application might be due to the synergistic effect produced by banana pseudostem vermicompost along with higher quantity of vermiwash. Similar findings of combined effect of vermicompost + organic booster were reported by Hangarge *et al.* (2004).

Number of leaves was significantly higher for aquatic weed vermicompost followed by banana pseudostem vermicompost. Similar finding of higher number of leaves due to vermicompost application was earlier reported by Ushakumari *et al* (1999). Vermiwash significantly produced higher number of leaves with maximum value for soil + foliar application of vermiwash at 30 and 60 DAS while foliar application alone produced maximum value at 90 DAS (Fig.4). Sivasubramanian and Ganeshkumar (2004) also reported higher number of leaves due to vermiwash application.

The leaf area index was higher in aquatic weed vermicompost applied plots and it was on par with banana pseudostem vermicompost at all growth stages. This might be due to the quickness in the availability of nutrients in vermicompost treated plots. As nitrogen and potassium uptake increases (Table 25), the extra protein produced allowed the plant leaves to grow larger and hence have more surface area available for photosynthesis. Similar findings of increased leaf area index in vermicompost treated plots were earlier reported by Manonmani and Anand (2002) in bhindi, Jat and Ahlawat (2004) in chickpea and Hiranmani *et al.* (2003) in chilli. Soil + foliar application of vermiwash resulted in maximum leaf area index at all growth stages than other methods of application. Vermiwash has high content of readily available forms of major and micronutrients (Jasmin. 1999) and the soil + foliar application might have resulted in a comparatively higher uptake of these of nutrients directly through foliage as well as through soil and has resulted in better growth giving larger leaf area. Similar finding of increased leaf area due to vermiwash application was reported by Jasmin (1999). The interaction effect of different sources of organic manure along with vermiwash application caused significant influence on leaf area index at 30 DAS. Aquatic weed vermicompost along with soil + foliar application of vermiwash produced the maximum leaf area index. This might be due to increased availability of nutrients especially, phosphorus by the action of both aquatic weed vermicompost and soil+foliar application of vermiwash leading to more leaf area (Tisdale *et al.*, 1995). Increased availability of phosphorus due to aquatic weed vermicompost application was earlier reported by Chaudhuri *et al.* (2001) and in vermiwash by Jasmin (1999).

Dry matter production was higher for aquatic weed vermicompost application at later stages of plant growth (60 DAS and 90DAS), while during early growth stage (30 DAS), it was on par with banana pseudostem vermicompost (Fig.5). The greater accumulation of dry matter production for aquatic weed vermicompost treated plots could be due to higher uptake of nitrogen, phosphorus and potassium (Table 25) which resulted in higher growth components such as increased number of leaves (Table 4) and leaf area index (Table 5). Similar increase in dry matter production in aquatic weed vermicompost treated plots was reported by Khandal and Bharadwaj (2002). Vermiwash application significantly increased dry matter production at 60 and 90 DAS (Fig.5). Soil + foliar application could produce more dry matter production than foliar application. The higher dry matter production in soil + foliar application of vermiwash might be due to the favourable influence of higher quantity of vermiwash given through soil and foliage. The data on height of plant (Table 2) and leaf area index (Table 5) substantiate this result. The higher dry matter production for soil + foliar application might be due to increased availability of readily available nutrients and growth promoting substances like IAA and IBA through this mode of application resulting in better growth of plants (Venkateswara, 2005). Similar findings of increased growth in vermiwash

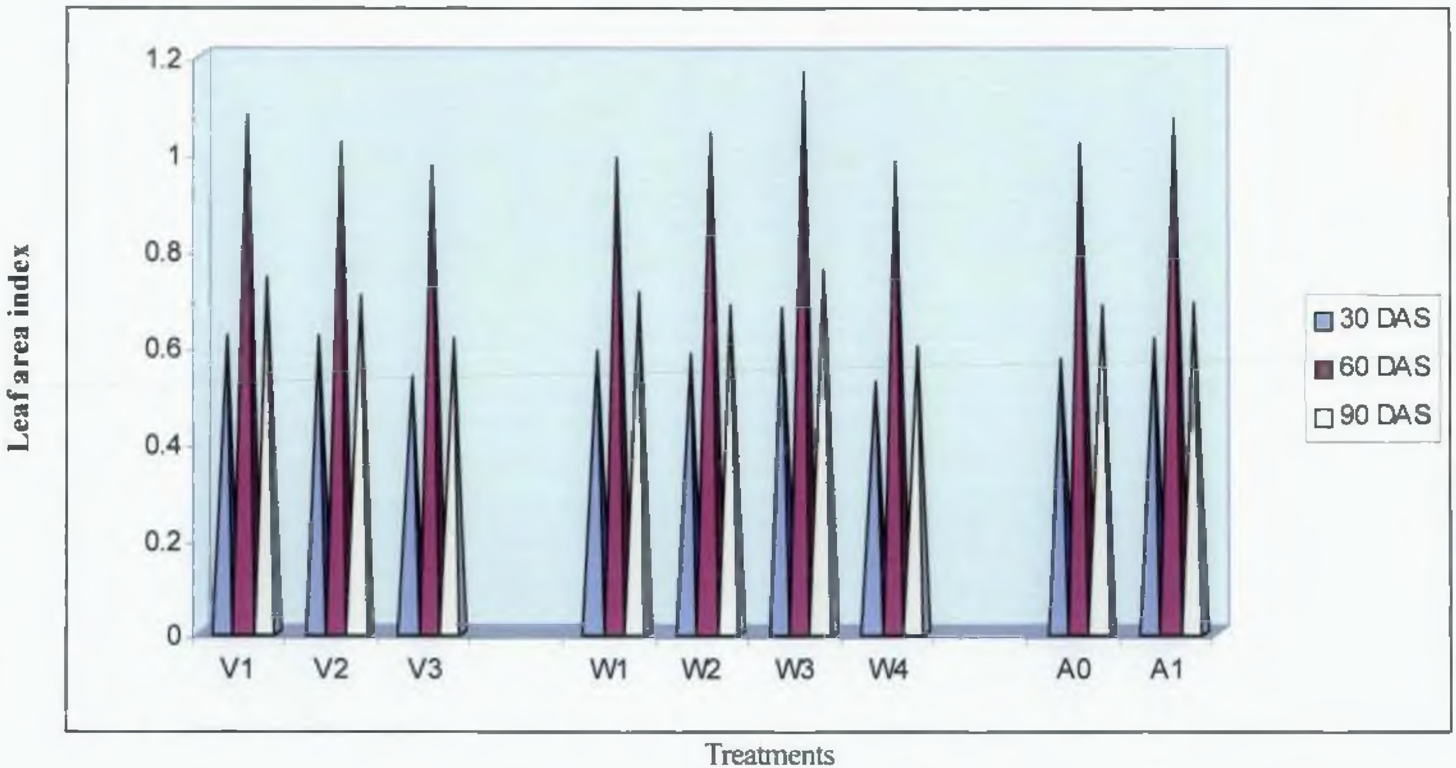


Fig. 4. Effect of different sources of organic manure, vermiwash and AMF on leaf area index

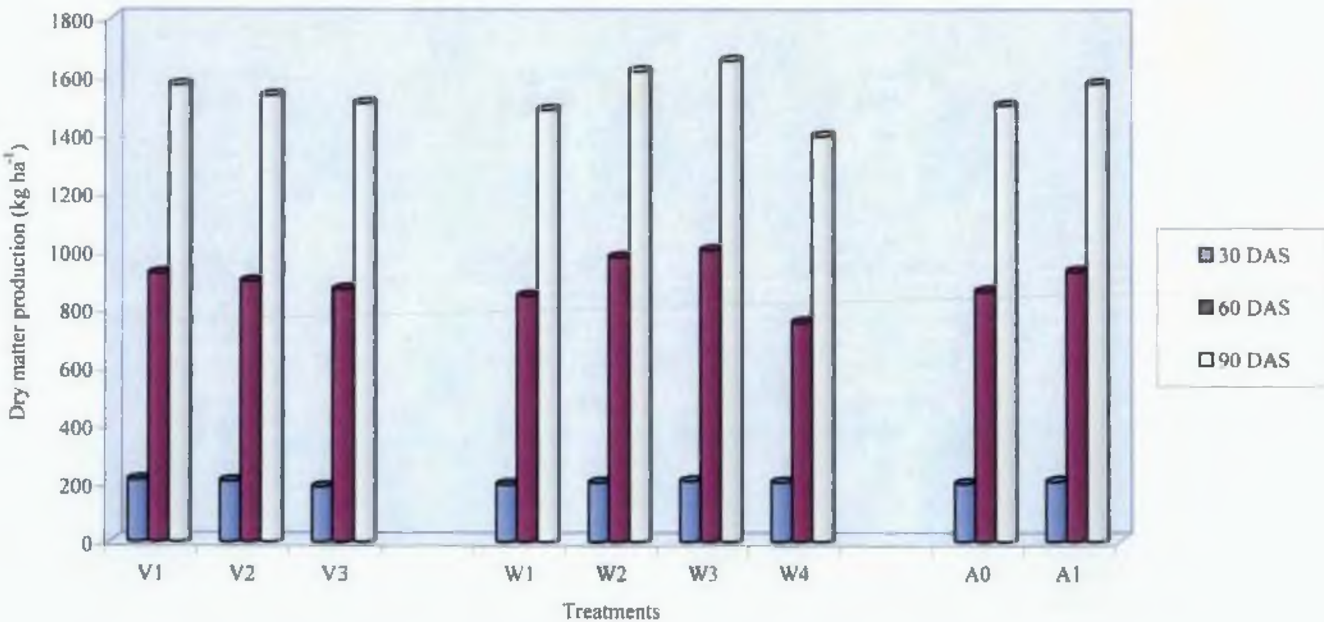


Fig. 5. Effect of different sources of organic manure, vermiwash and AMF on dry matter production (kg ha^{-1})

treated plants were reported by Venkateswara (2005) in bhindi and Thangavel (2003) in paddy.

Aquatic weed vermicompost along with soil + foliar application of vermiwash produced significantly higher dry matter production at 60 DAS (1053.79 kg ha^{-1}) and at 90 DAS (1729.05 kg ha^{-1}) compared to other treatments. This might be due to increase in plant height (Table 3) and leaf area index (Table 6) for these treatments.

5.1.2 Root Characteristics

Plants applied with banana pseudostem vermicompost had longer taproot which is comparable with aquatic weed vermicompost, while aquatic weed vermicompost applied plants had more root spread and was comparable with banana pseudostem vermicompost (Fig .6). Similar findings of increased root length due to vermicompost application was earlier recorded in bhindi by Shanthi and Vijayakumari (2002), in tomato by Samawat *et al.* (2001) and in green gram by Karmegam *et al.* (1999).

Vermiwash application showed significant influence in root spread and tap root length at the time of final harvest. Root spread and tap root length was higher for soil+foliar application while control treatment (water spray) showed least root spread (Fig.6). This might be due to the increased root proliferation of plants by the application of more quantity of vermiwash through soil and foliage, which might have led to the increased uptake of nutrients by plants, especially phosphorus (Table 25), since phosphorus is an essential element for root growth (Tisdale *et al.*, 1995).

5.1.3 Yield and Yield Attributing Characters

Aquatic weed vermicompost applied plants took minimum number of days for 50 per cent flowering (38days) while farmyard manure applied plants took maximum number of days (40 days). This might be due to easy availability of nutrients at early stages of growth, especially phosphorus. Earliness in flowering due to phosphatic fertilizers was reported by Thompson and Kelly (1957) and

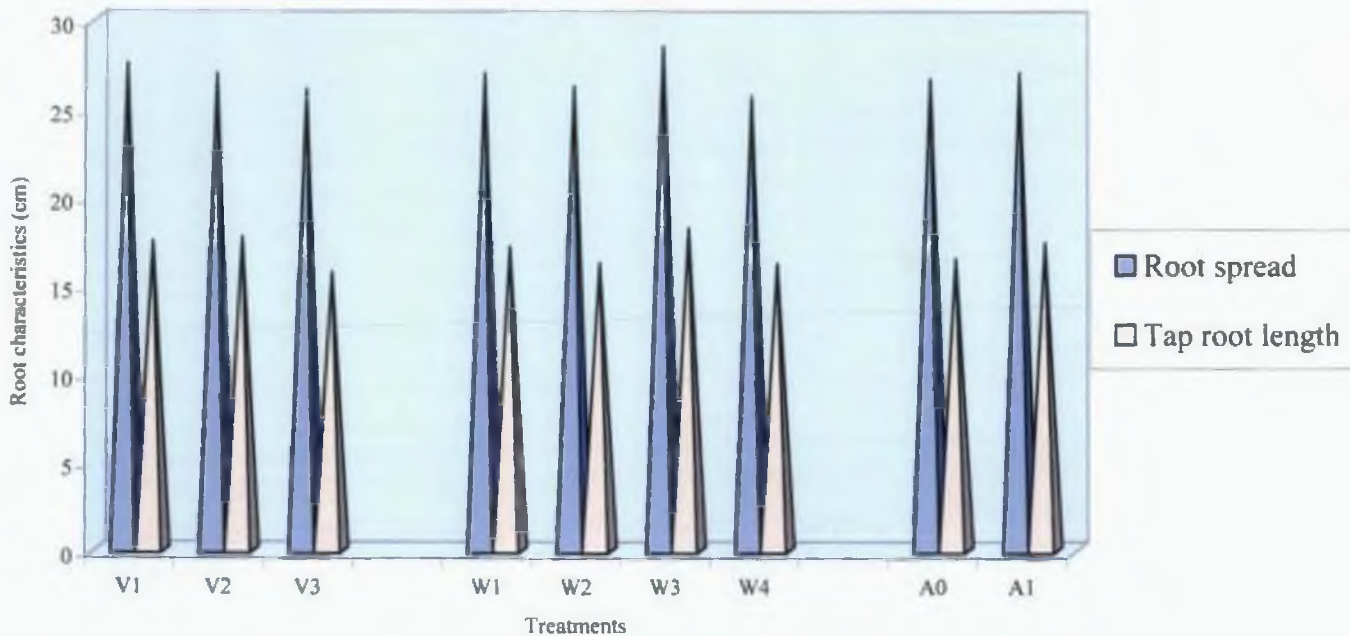


Fig. 6. Effect of different sources of organic manure, vermiwash and AMF on root characteristics of bhindi

Kamalanathan *et al.* (1978) in bhindi. Different sources of organic manure, significantly influenced number of flowers plant^{-1}, number of fruits plant^{-1}, fruit yield plant^{-1} and total fruit yield ha^{-1} (Fig. 7). The higher availability and uptake of nutrients might have enabled the plant to produce more number of flower buds which in turn increased the number of fruits. The increased fruit yield plant^{-1}and total fruit yield in aquatic weed vermicompost applied plants was due to the increased yield attributes like number of flowers plant^{-1} and fruits plant^{-1} (Table 13). The attack by fruit and shoot borer was also found to be less for aquatic weed vermicompost applied plants (Table 28). Similar findings of increased fruit yield in gourds and tomato when treated with water hyacinth vermicompost was reported by Hossain and Majid (1997).

Eventhough not significant, soil + foliar application of vermiwash produced more number of flowers, number of fruits, fruit yield plant^{-1}and total fruit yield ha^{-1} compared to other treatments (Fig.7). It is possible that in addition to the high nutrient status in vermiwash its alkaline nature (pH 8.7) might have ameliorated the soil reaction of the experimental field which had a pH of 4.8 resulted in better uptake of plant nutrients. In soil +foliar application of vermiwash, quantity of vermiwash obtained by plant was more. Moreover vermiwash contain growth promoting substances, group B vitamins, mucus deposit of epidermal cells and coelomic fluid produced by worms which contain plant hormones and chemical exudates as reported by Grapelli *et al.* (1987) and Tomati *et al.* (1983). These organic substances present in vermiwash might have produced a positive effect on fruit set which in turn had reflected in higher fruit yield. This was in line with the findings of Jasmin (1999) and Venkateswara (2005).

The number of seeds fruit^{-1} was higher for aquatic weed vermicompost treated plants (Table 20) and it was 9 per cent and 7 per cent more than that of farmyard manure and banana pseudostem vermicompost application respectively. Seed yield plant^{-1} (Table 22) was also higher for aquatic weed vermicompost which was 24 per cent and 19 per cent more than that of farmyard manure and

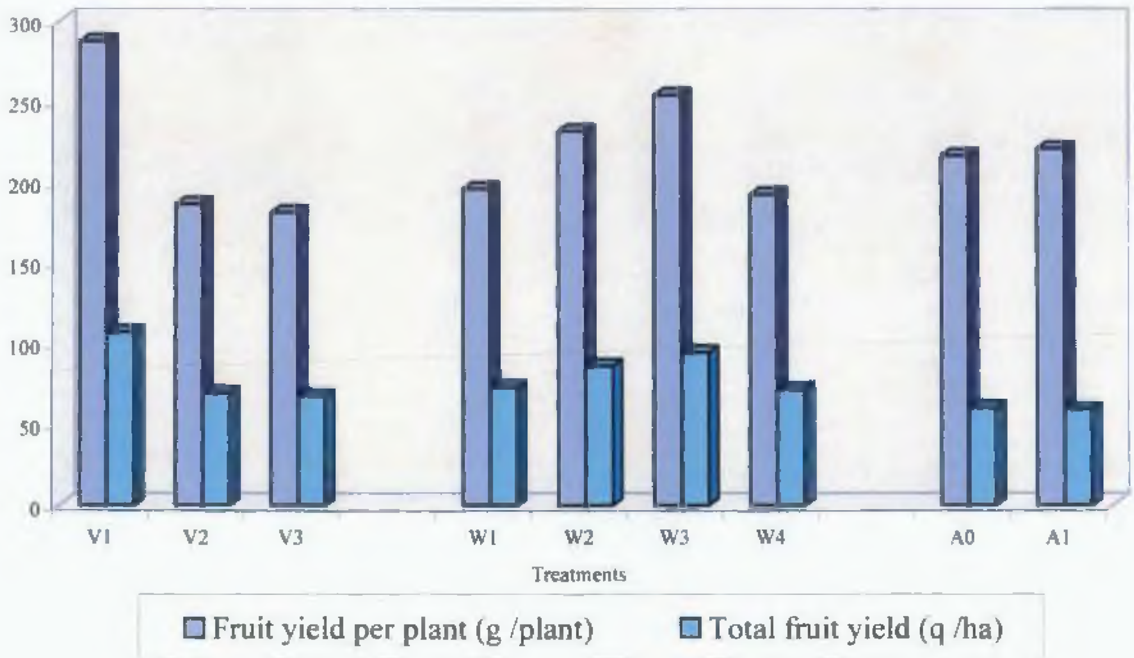


Fig. 7. Effect of different sources of organic manure, vermiwash and AMF on fruit yield plant^{-1} and total fruit yield of bhindi

banana pseudostem vermicompost application respectively (Fig.8). Increased seed yield due to aquatic weed vermicompost application was due to increased fruit yield, total fruit yield and number of seeds fruit^{-1}. The higher availability of nutrients viz. phosphorus and potassium might be one of the reasons for increased production of seeds in these treatments. Similar findings of increased seed yield with more potassium uptake was reported by Tisdale *et al.* (1995) and phosphorus uptake by Bhat and Singh (1996).

Vermiwash application significantly influenced number of seeds fruit^{-1}and seed yield (kg ha^{-1}) of which soil + foliar application showed maximum value which was comparable with foliar application of vermiwash (Fig.8). Foliar application was found to be better for seed production producing significant influence on number of seeds fruit^{-1}and seed yield ha^{-1} compared to soil application (Jasmin, 1995). But through soil + foliar application, quantity of vermiwash obtained was more. Hence the uptake of nutrients was more, especially phosphorus and potassium (Table 25). Similar findings of increased seed yield with more potassium uptake was reported by Tisdale *et al.* (1995) and phosphorus uptake by Bhat and Singh (1996). VW interaction significantly influenced number of seeds produced fruit^{-1}. Aquatic weed vermicompost along with soil + foliar application of vermiwash recorded maximum number of seeds fruit^{-1} which was on par with aquatic weed vermicompost with foliar application of vermiwash.

5.2 EFFECT OF AMF AND ITS INTERACTION WITH SOURCES OF ORGANIC MANURE AND VERMIWASH ON GROWTH AND YIELD ATTRIBUTING CHARACTERS

5.2.1 Growth Characters

Application of AMF favoured the growth of plants at later stages of growth. This can be possibly explained through the relative values of various growth components like plant height, number of leaves, leaf area index, dry matter production and root characters viz. root length and root – shoot ratio. The higher trend in these characters was due to the enhanced root conductivity which

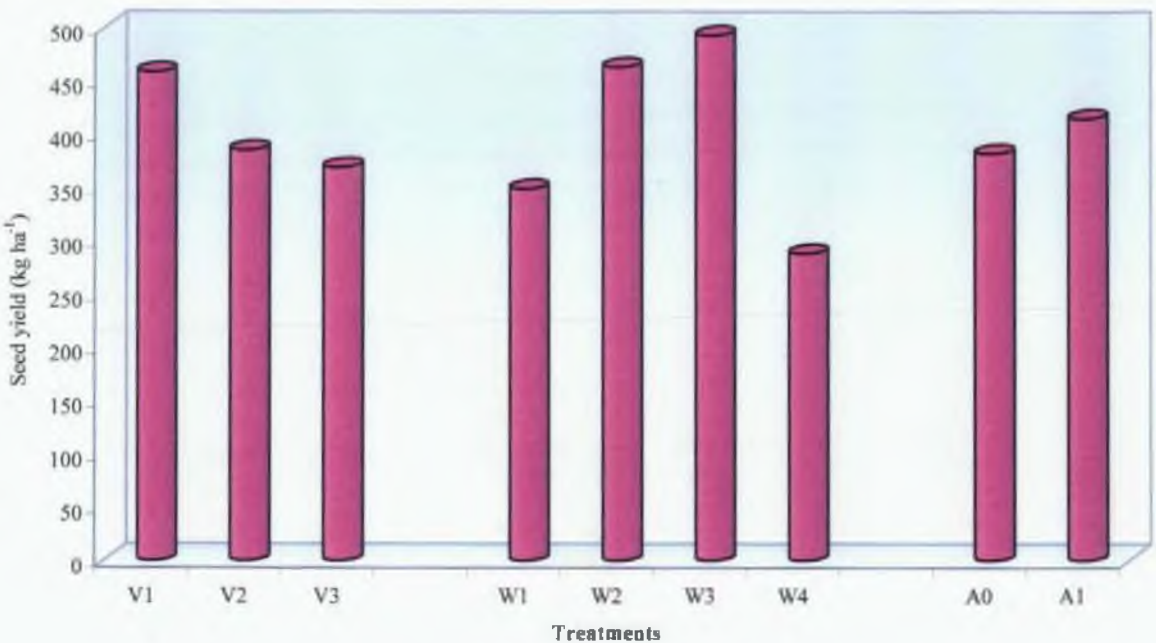


Fig. 8. Effect of different sources of organic manure, vermiwash and AMF on seed yield (kg ha^{-1}) of bhindi

led to better uptake of water and nutrients. This was in conformity with the findings of Levy and Krikun (1980) and Sivaprasad *et al.* (1990). Increase in plant height in AMF inoculated plants was earlier reported by Senapathi *et al.* (1986) and Kumar *et al.* (2001). Increased growth in okra due to AMF inoculation was reported earlier by Jothi *et al.* (2000) and Prabhu *et al.* (2003). VWA interaction was also significant at 90DAS, of which banana pseudostem vermicompost along with soil + foliar application of vermiwash and AMF recorded maximum plant height (Table 3). Here vermiwash application along with AMF might have paved way for easy availability of nutrients from vermicompost and hence increased plant height.

More number of leaves (Table 4) and high leaf area index (Table 5) was noticed in AMF inoculated plants. Effective utilization of resources led to more plant growth producing larger and more number of leaves resulting in high LAI. These results were in conformity with the findings of Nagaraju *et al.* (2000) and Rana *et al.* (2002). The interaction effect of vermiwash application along with AMF had significant influence on leaf area index at 60 and 90 DAS. Soil + foliar application of vermiwash along with AMF recorded significantly higher leaf area index. The synergistic effect produced by higher quantity of vermiwash along with AMF might have increased the leaf area index.

AMF inoculated plants produced high dry matter production at all growth stages than non inoculated plants (Fig.5). Effective AMF colonization (Table 11) and higher uptake of nutrients (Table 25) resulted in higher dry matter production. Similar findings of increased dry matter production due to AMF application was reported earlier by Rathore *et al* (1995), Hazarika *et al.* (2000) and Devi and Sitaramaiah (2001). Soil + foliar application of vermiwash with AMF recorded significantly higher dry matter production of 1045.13 kg ha^{-1} at 60 DAS and 1708.7 kg ha^{-1} at 90 DAS compared to other treatments. The combined effect of vermiwash along with AMF application has resulted in better plant growth and hence higher dry matter production. Aquatic weed vermicompost with AMF application recorded higher dry matter production of 960.71 kg ha^{-1} at 60 DAS and 1616.99 kg ha^{-1} at 90 DAS. The vermicompost application might have enhanced the activity of beneficial microbes like mycorrhizal fungi, resulting in higher dry matter production. This is in line with the findings of Kale *et al.* (1992). Increase in dry shoot weight with the application of vermicompost and AMF was earlier reported by Martinez *et al.* (1999). Different sources of organic manure along with vermiwash and AMF application was significant both at 60 and 90 DAS with aquatic weed vermicompost along with soil + foliar application of vermiwash and AMF recording significantly superior dry matter production of 1110.21 kg ha^{-1} at 60 DAS and 1820.19 kg ha^{-1} at 90 DAS(Table 9).This might be due to the fact that vermiwash application might have increased the beneficial effect of both aquatic weed vermicompost and AMF and hence paved way for easy availability of nutrients for the plant and hence better plant growth resulting in higher dry matter production.

5.2.2 Root Characteristics

AMF inoculated plants resulted in increased root growth and root – shoot ratio compared to non inoculated plants (Fig.6). The increase in root growth might be due to the increased uptake of phosphorus along with increased water availability. Similar findings of increased root growth due to AMF inoculation has been reported by Purakayastha and Choonkar (2000),Setua *et al.*(1999) ,Hazarika *et al.*(2000) and Jayakiran (2004).

Interaction effect of vermiwash and AMF was significant at 90 DAS with maximum value shown by soil + foliar application of vermiwash along with AMF application. Combined action of higher quantity of vermiwash along with AMF might have increased root proliferation (Table 10).

5.2.3 Yield and Yield Attributing Characters

Even though not significant AMF inoculated plants produced higher number of flowers plant^{-1}, setting percentage, fruit yield plant^{-1}and total fruit yield compared to non inoculated plants. Increased uptake of water and nutrients enhanced translocation of metabolites which might have contributed to increased yield attributes. Higher yield due to AMF inoculation was earlier reported by Sivaprasad (1998), and Mathew *et al.* (2003). Even though not significant, aquatic weed vermicompost along with soil + foliar application of vermiwash and AMF recorded maximum number of fruits (Table 14) compared to other treatment combinations and hence recording maximum fruit yield plant^{-1}and total fruit yield ha^{-1} ((Table 20). This might be due to the synergistic effect produced by the effect of these three components and also due to low attack by fruit and shoot borer on these plots.

AMF inoculation produced maximum seeds fruit^{-1}and seed yield (kg ha^{-1}) (Fig.8). This increased seed yield might be due to increased uptake of phosphorus and potassium (Table 25) in AMF inoculated plants. Similar findings of increased rice grain yield due to AMF inoculation was earlier reported by Soloiman and Hirata (1997) and Purakayastha and Choonkar (2001) and in bhindi by Senapathi (1986).

VWA interaction was significant with maximum number of seeds per fruit reported by aquatic weed vermicompost with soil + foliar application of vermiwash and AMF (Table 21) and hence produced maximum seed yield compared to other treatment combinations. The combined application of these treatments might have increased nitrogen, phosphorus and potassium uptake and hence increased seed yield(Table 23) .Similar findings of increased seed yield with the application of NPK+VAM was earlier reported by Chinnamuthu and Venkatakrishnan (2001).

5.3 EFFECT OF SOURCES OF ORGANIC MANURE, VERMIWASH AND THEIR INTERACTIONS ON QUALITY ASPECTS OF SEED

Different sources of organic manure produced significant influence on seedling vigour. Aquatic weed vermicompost and banana pseudostem vermicompost showed more or less same seedling vigour (Table 24). However higher seedling vigour was observed in plots treated with aquatic weed vermicompost while lowest seedling vigour was observed in farmyard manure. This was in conformity with the findings of Isaac (1996) in bhindi.

Even though not significant, higher seed viability and germination percentage were reported by aquatic weed vermicompost and banana pseudostem vermicompost compared to farmyard manure. Similar findings of increased seed viability and germination percentage in vermicompost treated plots were reported earlier by Pushpa (1996) in tomato.

Vermiwash application caused significant influence on germination percentage. of which soil + foliar application produced maximum germination percentage (90.83) while control plot (water spray) produced the least (84.16). However foliar application produced superior germination capacity of seeds compared to soil application. Similar finding of increased germination capacity of seeds by foliar application of vermiwash over soil application had been reported by Jasmin (1999) in tomato.

Vermiwash application also produced significant effect on seedling vigour. Soil + foliar application resulted in superior seedling vigour which was on comparison with foliar application alone while control treatment showed least seedling vigour (Table 24). Increase in seedling vigour in vermiwash application might be due to increased germination percentage, along with increased seedling shoot length and seedling root length.

5.4 EFFECT OF AMF ON QUALITY ASPECTS OF SEED

Even though not significant. AMF inoculation produced seeds with more germination capacity. vigour index and seed viability (Table 24). Similar findings of increased germination percentage due to AMF inoculation was reported by Kumar *et al.* (2001) in cowpea and Prabhu *et al.* (2003) in bhindi.

5.5 EFFECT OF SOURCES OF ORGANIC MANURE, VERMIWASH AND THEIR INTERACTIONS ON NUTRIENT UPTAKE

Nutrient uptake was significantly influenced by different sources of organic manure with maximum uptake for aquatic weed vermicompost (Fig.9). The enhanced root production, more vegetative growth along with higher dry matter production might have resulted in increased uptake of these nutrients. An

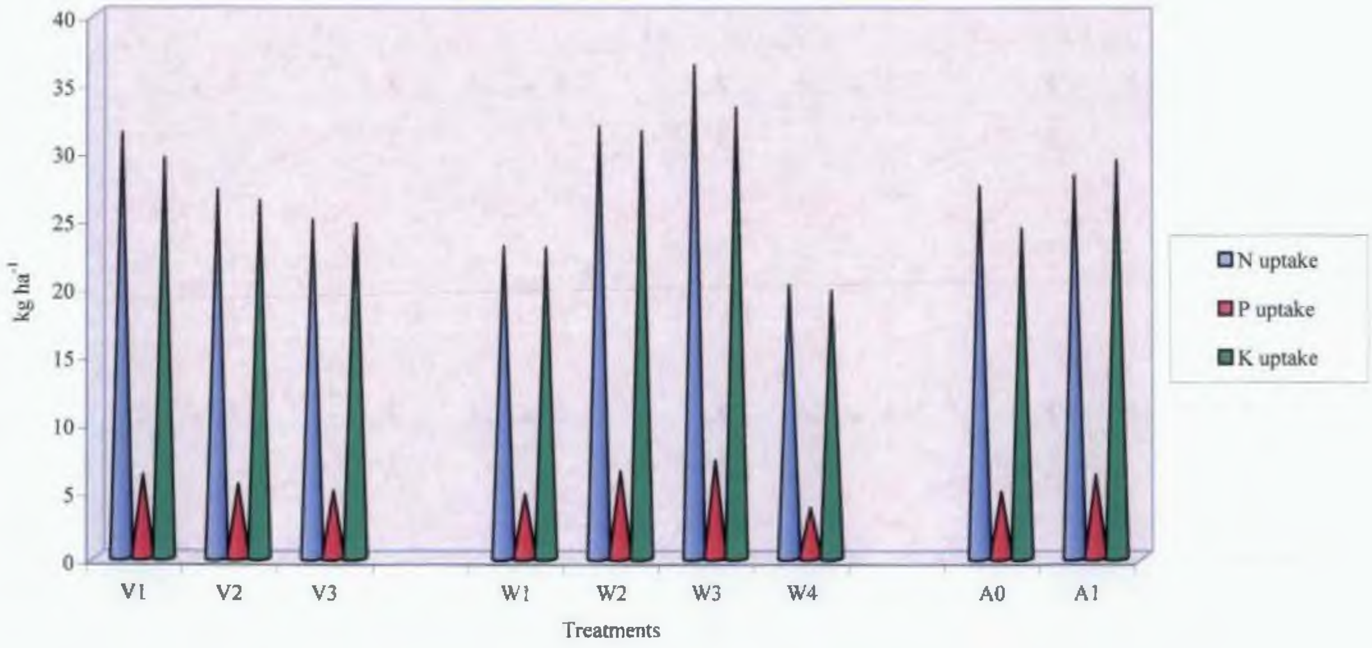


Fig. 9. Effect of different sources of organic manure, vermiwash and AMF on nutrient uptake (kg ha^{-1}) at harvest

increased uptake of around 25 per cent of nitrogen compared to farmyard manure and 15 per cent compared to banana pseudostem vermicompost was recorded by aquatic weed vermicompost. With regard to the uptake of phosphorus there was an increase of about 24 percent over farm yard manure and 11 per cent over banana pseudostem vermicompost by aquatic weed vermicompost (Table 25). Same trend was noticed in the case of potassium also. Here the percent of the uptake was 20 per cent over farmyard manure and 12 per cent over banana pseudostem vermicompost.

Increased availability of total nitrogen, phosphorus and potassium in aquatic weed vermicompost, due to the passage of the plant materials through the gut of the worms were earlier reported by Chaudhuri *et al.* (2001). Mani and Perumal (2002) also reported that water hyacinth increases the phosphorus availability due to the presence of organic acids, so that insoluble phosphate is made available by the action of these organic acids. Talukdar *et al.* (2001) also reported highest potassium content in water hyacinth vermicompost.

Vermiwash application produced significant effect on nutrient uptake by plants viz. nitrogen, phosphorus and potassium (Fig.9). Increased nutrient uptake was recorded by soil + foliar application of vermiwash. Here quantity of vermiwash available for plants was more, so its beneficial effect was also more.

Increase in nitrogen uptake due to vermiwash application might be due to the alkaline nature and nutrient content of vermiwash. Vermiwash also contain nitrogen fixing organisms (Bhawalker, 1992) which can supplement soil available nitrogen by their metabolic reactions. The vermiwash application also caused significant increase in phosphorus uptake. The higher content of phosphorus in vermiwash as well as increased mineralization of soil phosphorus as a result of the production of organic acids during decomposition of vermicompost may be the reason for increased phosphorus uptake by the plants. The solubilization of phosphorus by the micro organisms present in vermiwash may be attributed to excretion of organic acids like citric acid, glutamic acid, succinic acid, lactic acid, oxalic acid etc. as proposed by Subbarao (1988). Similar findings of increased 'P' uptake due to vermiwash application was reported earlier by Maheswari *et al.*(2003) and Karuna *et al.* (1999).Increased 'K' uptake due to vermiwash application might be due to the fact that vermiwash contain 'K' in a highly soluble form. Jasmin (1999) reported that plant uptake of major nutrients like nitrogen, phosphorus, and potassium was maximum for highest concentration of vermiwash applied through foliage along with full inorganic fertilizers.

5.6 EFFECT OF AMF AND ITS INTERACTION WITH SOURCES OF ORGANIC MANURE AND VERMIWASH ON NUTRIENT UPTAKE

AMF inoculated plants caused significant effect on phosphorus and potassium uptake (Fig. 9). Root conductivity and root activity were more in AMF inoculated plants. The enhanced root proliferation and better nutrient assimilation along with total dry matter production might have resulted in increased uptake of nutrients especially phosphorus and potassium. Similar findings of increased uptake of nitrogen, phosphorus and potassium uptake due to AMF application was earlier reported by Jayakiran (2004), potassium uptake by Paul and Clerk (1989) and phosphorus uptake by Sinha *et al.* (2004). WA interaction was significant with maximum value of potassium uptake for soil + foliar application of vermiwash along with AMF. The increased quantity of vermiwash enhanced the availability of potassium and hence increased potassium uptake by plants.

5.7 EFFECT OF SOURCES OF ORGANIC MANURE AND THEIR INTERACTIONS ON AVAILABLE SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

Organic manure addition had significant influence on residual nutrient status of the soil (Fig.10). The maximum value for available nitrogen was given by farmyard manure and least value for aquatic weed vermicompost (Table 26). The lower value of available nitrogen for aquatic weed vermicompost might be due to the increased uptake of nutrient by the plant. The phosphorus availability was higher for aquatic weed vermicompost. since phosphorus solubilising capacity of vermicompost is more which might have resulted in the increased availability of phosphorus. Reddy and Mahesh (1995) also reported higher

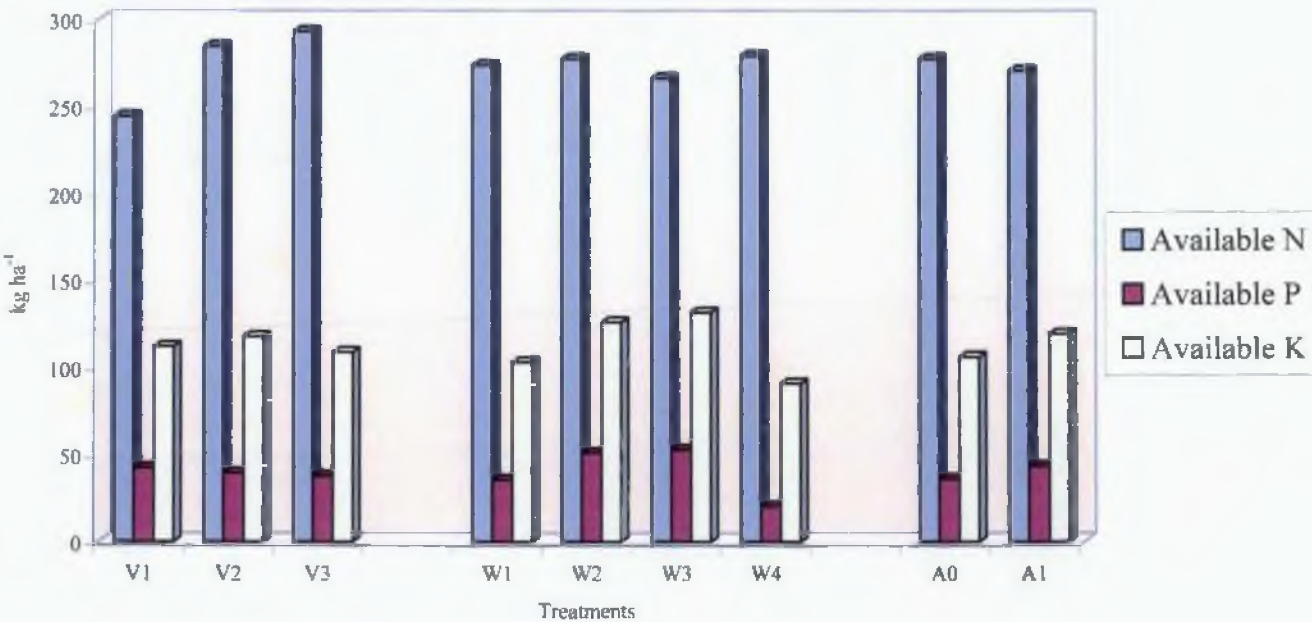


Fig. 10. Effect of different sources of organic manure, vermiwash and AMF on available nitrogen, phosphorus and potassium after the experiment

phosphorus availability in soil due to the application of vermicompost compared to farmyard manure. Organic manure application could record higher potassium availability in soil. Vermicompost can favourably influence soil properties and can ensure steady supply of nutrients including potassium throughout the growth period. Vermicompost is a very rich source of potassium compared to farmyard manure and this might have resulted in high potassium status in treatments with vermicompost. Bhawalker (1992) could obtain 10 per cent more of K_2O in soils with vermicompost application.

The control treatment (water spray) recorded maximum available nitrogen status after the experiment compared to vermiwash application (Table 26). This might be due to increased uptake of nitrogen in vermiwash treated plots compared to water spray. Vermiwash application caused significant influence on available phosphorus and potassium after the experiment. The alkaline nature of vermiwash might have ameliorated the acidity of the soil of the experimental field and thereby increased the content of available phosphorus in the soil. Vermiwash contain potassium in soluble form and hence increased available potassium status. Similar findings of increased availability of phosphorus and potassium were earlier reported by Jasmin (1999).

Interaction effect of different sources of organic manure along with vermiwash application was significant with maximum value of 'K' availability for banana pseudostem vermicompost with soil+foliar application of vermiwash. Similar findings of increased availability of nitrogen, phosphorus and potassium in soil due to combined effect of organic – organic sources were earlier reported by Hangarge *et al.* (2004).

5.8 EFFECT OF AMF AND ITS INTERACTION WITH SOURCES OF ORGANIC MANURE AND VERMIWASH ON AVAILABLE SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

AMF produced significant influence on available phosphorus and potassium at harvest of crop while available nitrogen was significantly lower than non inoculated plants (Table 26). The lowest value of available nitrogen might be due to increased uptake of nitrogen by AMF. In addition to phosphorus solubilization, this micro organism could mineralize organic phosphorus into soluble form. Thus microbes rendered more phosphorus into soil solution than that is required for their own growth and metabolism. This might be the reason for increased soil 'P' in AMF received plots. Similar result of mineralization of phosphorus through the production of organic acids was reported by Levy and Krikun (1980). Singh and Singh (1993) also reported enhanced availability of diffusion dependent nutrient like phosphorus by AMF.AMF inoculated plants also recorded significant effect on potassium availability. AMF benefits plants through the expansion of soil volume by which nutrients like potassium are made more available. This is in accordance with the findings of Clark and Zeto (2000) and Gill *et al.* (2000).

VA interaction was significant with higher available nitrogen status in farmyard manure with AMF and farmyard manure without AMF. This might be due to less uptake of nitrogen by plants in these plots. WA interaction produced significant effect on 'P' availability in soil, of which soil + foliar application of vermiwash along with AMF recorded maximum 'P' availability. This might be due to the combined effect of both these increased quantity of vermiwash and AMF on phosphorus solubilisation.

WA interaction was significant with soil + foliar application of vermiwash along with AMF produced significantly higher value for available potassium status. Similar findings of increased availability of nitrogen, phosphorus and potassium in soil due to combined effect of organic + organic sources were earlier reported by Hangarge *et al.* (2004).

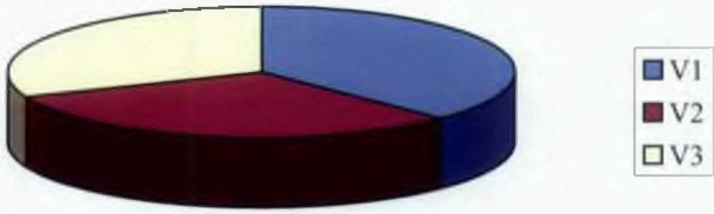
5.9 EFFECT OF SOURCES OF ORGANIC MANURE, VERMIWASH AND AMF AND THEIR INTERACTIONS ON PERCENTAGE OF FRUITS INFESTED BY FRUIT AND SHOOT BORER

Different sources of organic manures and vermiwash produced significant difference in percentage of fruits infested by fruit and shoot borer (Table 28). Percentage infestation was maximum in farmyard manure treated plots, while aquatic weed vermicompost recorded least infestation of fruits. This might be due to increased uptake of potassium in aquatic weed vermicompost treated plants compared to farmyard treated ones, since potassium gives resistance to pest and diseases incidence. Soil + foliar application of vermiwash caused least infestation of fruits, while water spray produced maximum infestation of fruits. Similar findings of increased resistance to pest and diseases by vermicompost application was earlier reported by Bhatnagar and Palta (1996) and vermiwash application by Venkataswara *et al.* (2005) in bhindi. AMF inoculation could not produce any significant influence in percentage of fruits infested by fruit and shoot borer

5.10 EFFECT OF SOURCES OF ORGANIC MANURE, VERMIWASH, AMF AND THEIR INTERACTIONS ON ECONOMICS OF SEED PRODUCTION

Different sources of organic manure, vermiwash and AMF had significant influence on BC ratio (Fig. 11). Aquatic weed vermicompost treated plots recorded maximum BC ratio of 2.27 compared to farmyard manure (Table 29), since the returns produced is more in these plots. Percentage increase in BC ratio due to aquatic weed vermicompost is about 17 per cent over farmyard manure. Similar findings of reduced cost of cultivation in bhindi by the application of vermicompost were earlier reported by Ushakumari *et al.* (1999) and in tomato by Patil *et al.* (1998). Vermiwash application also significantly influenced BC ratio with soil + foliar application of vermiwash recorded the maximum value (2.43). Increased seed yield might be the reason for this high BC ratio. AMF also produced maximum BC compared to non inoculated plants. Even though not significant. VWA interaction had influenced the BC ratio with aquatic weed vermicompost along with soil + foliar application of vermiwash and AMF giving maximum value of 2.79 and least by FYM along with water spray and without AMF (1.32).

Based on the results of the experiment, it is concluded that for getting maximum profit through the production of quality seeds in bhindi, application of



Sources of organic manure

Vermiwash

AMF

Fig. 11. Effect of different sources of organic manure, vermiwash and AMF on BC ratio

aquatic weed vermicompost along with soil + foliar application of vermiwash and field application of AMF is ideal.

Summary

6. SUMMARY

A field investigation was conducted during June to September 2004 at College of Agriculture, Vellayani to evaluate the efficiency of different sources of organic manure, vermiwash and AMF application on quality seed production of bhindi. The findings of the investigation are summarized below.

Maximum plant height was noticed in banana pseudostem vermicompost followed by aquatic weed vermicompost at all growth stages. Of different modes of vermiwash application, soil + foliar application produced significantly higher plants followed by foliar application alone. AMF inoculated plants recorded maximum plant height only at later stages than non inoculated ones. Banana pseudostem vermicompost along with soil + foliar application of vermiwash recorded maximum plant height at all growth stages.

Interaction effect was significant at later stages with maximum plant height for aquatic weed vermicompost with soil + foliar application of vermiwash and AMF which was comparable with banana pseudostem vermicompost with soil + foliar application of vermiwash and AMF.

Aquatic weed vermicompost recorded higher number of leaves with maximum leaf area index at all growth stages compared to other sources of organic manure. Soil + foliar application of vermiwash produced maximum number of leaves at early stage of growth while foliar application of vermiwash registered maximum number of leaves at later growth stage. AMF application produced maximum number of leaves only at later growth stage. Soil + foliar application of vermiwash recorded maximum leaf area index at all growth stages while AMF application influenced leaf area index only at 60 DAS.

Aquatic weed vermicompost recorded higher dry matter production while farmyard manure recorded lower dry matter production at all growth stages. Soil + foliar application of vermiwash along with AMF recorded maximum dry matter production at later growth stage. The interaction effect was significant with aquatic weed vermicompost along with soil + foliar application of vermiwash and AMF registered maximum dry matter production at later growth stage.

Different sources of organic manure, AMF and their interactions did not show any significant influence on root spread. Vermiwash application showed significant variation in root spread with maximum value shown by soil + foliar application. Superior tap root length was noticed for banana pseudostem vermicompost and more or less same tap root length was observed for aquatic weed vermicompost. Soil + foliar application of vermiwash showed higher tap root length than other modes of application. AMF inoculated plants showed higher tap root length than non inoculated ones.

Vermicompost, farmyard manure, vermiwash and their interactions could not significantly influence root shoot ratio. But AMF significantly influenced root shoot ratio with higher root shoot ratio in treated plants.

Number of days taken for 50 per cent flowering was significantly delayed with farmyard manure and banana pseudostem vermicompost while those supplied with aquatic weed vermicompost took only 38 days. Vermiwash, AMF and their interactions did not produce any significant influence on days for 50 per cent flowering.

Aquatic weed vermicompost applied plots recorded maximum number of flowers plant^{-1}, fruits plant^{-1}, setting percentage and length and girth of fruits compared to banana pseudostem vermicompost and farmyard manure. Vermiwash, AMF and their interaction did not produce any significant influence on number of flowers plant^{-1}, fruits plant^{-1} and setting percentage.

Increased fruit yield, total fruit yield, maximum number of seeds fruit^{-1} and weight of seeds fruit^{-1} was recorded by aquatic weed vermicompost followed by banana pseudostem vermicompost.

Aquatic weed vermicompost produced significantly higher seed yield ha^{-1}. Soil + foliar application of vermiwash also produced significantly higher seed yield ha^{-1}. AMF application produced significant effect on seed yield with maximum seed yield in AMF treated plots.

About the quality aspects of seed, aquatic weed vermicompost and banana pseudostem vermicompost showed more or less same seedling vigour. Soil + foliar application of vermiwash and foliar application alone caused significantly higher seedling vigour.

Aquatic weed vermicompost caused significantly higher nitrogen, phosphorus and potassium uptake. Soil + foliar application of vermiwash recorded maximum nitrogen, phosphorus and potassium uptake while AMF application caused maximum phosphorus and potassium uptake while no significant effect on nitrogen uptake was shown by AMF application.

Farmyard manure recorded significantly higher available nitrogen status in soil after the experiment. Water spray recorded maximum available nitrogen status after the experiment. Non AMF treated plots recorded maximum available nitrogen status. Aquatic weed vermicompost recorded significantly higher available phosphorus status while available potassium status was maximum for banana pseudostem vermicompost. Soil + foliar application of vermiwash recorded maximum available phosphorus and potassium status. AMF application also produced significant influence on available phosphorus and potassium status.

Percentage of infestation of fruit and shoot borer was maximum in farmyard manure and in water spray. While AMF and their interaction was not significant.

Aquatic weed vermicompost treated plots with soil + foliar application vermiwash and AMF recorded maximum BC ratio.

Future line of work

Potential of AMF in improving the growth and yield parameters in bhindi should be studied in detail. Effect of different sources of vermicompost on growth, yield and production of quality seeds of various crops should be attempted.

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EFFICACY OF VERMICOMPOST, VERMIWASH AND AMF ON QUALITY SEED PRODUCTION OF BHINDI

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ABSTRACT

An experiment was conducted at College of Agriculture, Vellayani during June to September of 2004 to evaluate the efficacy of vermicompost, vermiwash and AMF on quality seed production in bhindi. The experiment was laid out in split plot design with two replications. The main treatments were aquatic weed vermicompost, banana pseudostem vermicompost and farmyard manure along with vermiwash through soil application, foliar application, soil + foliar application and control treatment as water spray. The subplot treatments consisted of AMF application and without AMF application.

Taller plants were observed in banana pseudostem vermicompost and aquatic weed vermicompost treated plots. Significantly higher number of leaves with high leaf area index and dry matter production was noticed in aquatic weed vermicompost compared to other organic manures. Days for 50 per cent flowering was found maximum for farmyard manure. Aquatic weed vermicompost also showed better root characteristics along with yield attributes such as number of flowers plant^{-1}, number of fruits plant^{-1}, fruit yield plant^{-1}, total fruit yield ha^{-1}, number of seeds fruit^{-1} & seed yield ha^{-1} with better seed quality parameters like seed viability, seeding vigour and germination percentage.

Among the modes of vermiwash application, soil + foliar application of vermiwash was found better in showing superior trends in plant height, number of leaves, leaf area index, dry matter production, number of flowers and fruits plant^{-1}, fruit yield plant^{-1}, total fruit yield and seed yield ha^{-1} with better seed quality i.e., seedling vigour and germination percentage.

AMF application also showed maximum plant height, leaf area index, dry matter production, root length, root - shoot ratio, fruit yield $plant^{-1}$, total fruit yield, weight of seeds $fruit^{-1}$ and seed yield ha^{-1}.

Higher BC ratio was found in aquatic weed vermicompost, soil + foliar application of vermiwash and in AMF. So aquatic weed vermicompost along with soil + foliar application of vermiwash and AMF is ideal for quality seed production in bhindi.

Appendix

APPENDIX - I

Weather data for the cropping period
(2nd June – 2nd September 2004) – weekly averages

Standard week	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	Evaporation (mm day $^{-1}$)
	Minimum	Maximum			
21	23.83	30.96	78.20	80.90	2.47
22	24.02	30.69	18.00	82.50	2.92
23	22.84	29.84	86.40	84.64	2.73
24	23.07	30.00	67.20	87.35	2.54
25	23.67	30.32	59.00	82.28	3.69
26	23.60	30.51	18.00	81.86	3.66
27	23.64	30.77	17.40	83.36	3.74
28	22.79	29.61	87.40	84.64	3.40
29	22.93	29.47	153.90	83.50	3.19
30	23.69	29.61	31.00	85.79	3.17
31	24.40	29.99	7.80	83.50	4.03
32	22.51	30.07	68.50	82.50	3.97
33	22.68	29.40	15.80	82.36	3.17
34	23.50	30.96	0	78.42	4.82
35	23.50	30.74	0	76.92	4.97