INTEGRATED NUTRIENT MANAGEMENT IN SUNFLOWER (*Helianthus annuus* L.)

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CERTIFICATE

This is to certify that the thesis entitled "**INTEGRATED NUTRIENT MANAGEMENT IN SUNFLOWER (*Helianthus annuus* L.)**" *submitted by* **Mr.SURESH V. DODAMANI** *for the degree of* MASTER OF SCIENCE (AGRICULTURE) *in* **AGRONOMY** *of the College of Agriculture, Raichur, University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

RAICHUR
November, 1997

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Affectionately Dedicated
To My
Beloved Parents

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

I. INTRODUCTION

Oilseed crops occupy an important place next to food grains in the Indian economy. The oils not only form the essential part of human diet, but also serve as an important raw material for the agro-based industries. India is one of the largest producers of Oilseeds in world and has achieved self-sufficiency in oilseeds production. However, the demand for the vegetable oil is going to increase steadily in the coming years due to increase in consumption and also increase in population. It is estimated that at the end of the present century the human population would be about 1000. In India, the per capita per year consumption of vegetable oils is only 6.97 kg as against 22 kg in the developed countries. Oilseed production assumes paramount importance in the country because of the wide gap in demand and supply, which is forcing our country to import vegetable oil at an enormous annual expense. The need of the hour is therefore, to find out, the sources and methods to increase the productivity of vegetable oil and to reduce the dependence on import of oils and save the colossal drain of valuable hard currency.

Sunflower is an important oilseed crop in the world and ranks third, next only to groundnut and soybean in the total production of oilseeds. It is the only plant grown world wide on a large scale that originated and domesticated in Southern united states and Mexico. World wide interest in the crop aroused during 1960's and by 1980 Sunflower became the second most important source of edible vegetable oil in the world.

Sunflower is grown on an area of 27.37 million hectare with a production and productivity of 25.02 million tons and 1171 kg per hectare respectively in the world. In India, it occupies an area of 2.75 million hectare with a production of 1.30 million tons and productivity of 473 kg per hectare (Anon., 1996a). In Karnataka, sunflower was introduced in early seventies. Now the crop has been well accepted by the farming community because of desirable attributes such as short duration, photoperiod insensitivity, adaptability to wide range of soil and climatic condition, drought tolerance, lower seed rate, high seed multiplication ratio, high quality of edible oil and higher content of polyunsaturated fatty acids. The sunflower oil is known to have cholesterol lowering property (Giriraj, 1988).

Karnataka stands third with respect to area but it stands first with respect to production of sunflower in India. In Karnataka, sunflower is grown on an area of 0.36 million hectares with a production of 0.15 million tons and productivity of 409 kg per hectare.

India has made spectacular break through in production and consumption of fertilizers during the last four decades. But consumption of nonrenevable form of energy (i.e., chemical fertilizers) will be quite a limiting factor for increasing agricultural production in future, because of escalating energy cost. Chemical fertilizers are not available at affordable prices to the farmers. Moreover, the unbalanced and continuous use of chemical fertilizers in intensive cropping system is leading to imbalance of nutrients in soil which has adverse effect on soil physico-chemical properties and also on crop yields. The soil health and ecological hazards due to long term excessive use of chemical fertilizers also pose a serious problem.

Although, chemical fertilizers are playing a crucial role to meet the nutrient requirement of the crop, persistent nutrient depletion is posing a great threat to sustainable agriculture. Therefore, integrated use of all the sources such as chemical fertilizers, organic manures and biofertilizers is the need of the hour. The importance of organic manures in promoting soil health and better plant nutrition has started receiving much recognition in the world as a whole in recent years. The supplementary and complementary use of organic manures and biofertilizers along with chemical fertilizers improves physico-chemical properties besides improving the efficiency of applied fertilizers. Farm yard manure application to the crops is being practiced since many years. Beneficial effect of earth worms and their cast were known as early as in Darwin's era. But the potential of vermicompost to supply nutrients and to support beneficial microbes is being recognised recently. Further, a special group of micro-organisms are also used as a biofertilizers. The phytase enzyme produced by these micro-organisms will help in solubilizing the fixed phosphorus. However, information

on the effect of combined application of farm yard manure, vermicompost and biofertilizer with chemical fertilizer is meagre. Keeping these points in view, a field experiment was conducted at Agricultural college farm, Raichur during *rabi* 1996 to know the " Response of Sunflower to organic and inorganic sources of nutrients" with the following objectives.

1. **To know the effect of organic manures, biofertilizers and chemical fertilizers singly and in combination on the growth, yield and oil content in sunflower.**
2. **To know the synergestic effect of organic manures and biofertilizers for supplementing and complementing the use ofchemical fertilizers**
3. **To work out the economics of integrated nutrient management in sunflower.**

Review of Literature

II. REVIEW OF LITERATURE

A brief review of the literature pertaining to the present investigation on the effect of organic manures, biofertilizers and inorganic fertilizers on crop growth, yield components, yield and oil content of sunflower are made and presented briefly in this chapter.

2.1 EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM ON CROP PLANTS

Nitrogen is a component of protoplasm, proteins, nucleic acids, chlorophyll and plays a vital role both in vegetative and reproductive phase of crop growth. Phosphorus is an important constituent of nucleoproteins, high energy compounds such as ATP and plays a key role in energy transfer in the metabolic processes. Potassium is essential for carbohydrate metabolism and synthesis of proteins. regulation of activities of various essential mineral elements, activation of various enzymes and adjustments of stomatal movement and water relations.

2.1.1 Growth components and growth of sunflower

Doroshenko (1969) reported that phosphorus produced greater effect on photosynthesis in the early crop growth stages. Mukundan (1972) and El- Sayeed *et al.* (1984) observed significant effect of phosphorus on the final height of plant, stem girth, number of leaves per plant, LAI, dry matter at 30 and 60 DAS. Somasundaram and Iruthayaraju (1979) observed that irrigation and phosphorus significantly influenced the LAI and CGR, but the effect on NAR and RGR was not significant. However, irrigation at 1.05 IW/CPE ratio with 90 kg phosphorus per hectare recorded highest LAI and CGR at all stages of plant growth.

Ahmar *et al.* (1980) observed that application of 75 kg N per hectare significantly increased all characters studied except 50 per cent flowering. Tripathi and Kalra (1981) found that highest levels of N (120 kg/ha) significantly delayed the flower-bud initiation, flower opening and maturity as compared to 50 and 40 kg N also noticed with regard to yield attributes. However, the differences were non significant between 50 and 75 kg P_2O_5 per hectare.

Ramaswamy *et al.* (1974) revealed that application of nitrogen increased the oil content in seeds (44.55%) upto 50 kg N per hectare and further increase in N level decreased the oil percentage. Singh *et al.* (1975) reported that addition of 20 kg N per hectare to sunflower under rainfed condition enhanced the seed yield by 19 per cent over control and further, addition had no effect but Phosphorus at 30 kg per hectare recorded 17.4 per cent higher seed yield.

Adiseshaiah *et al.* (1978) observed significant increase in the seed yield due to application of phosphorus upto 45 kg P_2O_5 per hectare over control under rainfed condition. Daulay and Singh (1980) reported an increase in the seed yield of sunflower from 0.94 to 1.30 tonnes per hectare with increasing levels of P_2O_5 from 0 to 90 kg per hectare. This increased yield was attributed to yield attributes like head diameter, number of seeds per head and 1000-seed weight with 90 kg P per hectare. No response to further increase in phosphorus level was noticed.

Tripathi and Kalra (1981) recorded increased head diameter, number of seeds per head, seed yield and oil content of sunflower with application of 50:60:60 kg NPK per hectare. They also noticed decreased seed oil content with higher rates of N and increased oil content with applied P and K.

Sreeramulu and Rao (1980) reported that increasing fertilizer dose from no fertilizer to 60:39.3:49.50 NPK kg per hectare decreased the central sterility from 40.5 to 31.7 per cent and increased the seed yield from 0.71 to 1.40 tonnes per hectar. Palanivel and Ramanathan (1981) obtained oil content of 45.9 per cent and protein content of 21.79 per cent in sunflower with the application of 80-40-60 NPK kg per hectare. Certain P containing enzymes play an important role in fatty acid synthesis in seeds. The seed oil content and oil yield increased with increase in phosphorus application (Chaudhari and Paturde, 1981).

Muthuvel and Manickam (1982) found that sunflower seed and oil yield were significantly higher under those treatments which received fertilizer as compared to control. However, the difference among the fertilizer levels, was not significant. EL-Sayeed *et al.* (1984) reported that the head diameter, 1000-seed weight and seed yield increased with increasing P-application.

Dzanagov and Sokaey (1986) found that combined application of 45 kg N and 135 Kg P and 45 Kg K_2O per hectare increased yields by 0.89 tonnes per hectare compared to control. Gaur *et al.* (1987) reported that grain yield and oil content of sunflower was directly associated with increased levels of N and P. They concluded that 50 kg N and 30 kg P_2O_5 per hectare was optimum for stabilising the yield and oil content in sunflower. There was no response to K application on the yield and oil content of sunflower under rainfed condition.

Nazir et al. (1987) found increased sunflower seed yield with the application of 75 kg N + 50 kg P_2O_5 + 50 kg K_2O per hectare (2.78 t/ha). Singh *et al.* (1987) revealed that increasing rate of N application showed a consistent and significant increase in protein content in the sunflower seed at harvest upto 160 kg N per hectare but a decreasing trend was observed in oil content.

Toncea *et al.* (1987) reported that application of 120 kg N + 80 kg P + 80 kg K per hectare significantly increased the seed yield (3.4 t/ha) when compared to control (2.6 t/ha). Sharm and Gaur (1988) obtained increased seed yield with increasing level of nitrogen from 30, 60 and 90 kg per hectare (1.80, 2.08 and 2.28 t/ha respectively), and decreased oil content with increased levels of nitrogen (42.99, 42.95 and 40.49 % respectively).

Shin (1988) obtained highest seed yield of sunflower with application of 120:80:80 NPK kg per hectare and did not find any effect on oil content of sunflower. Chaniara et al. (1989) found that increasing N rates increased yields upto 60 kg N per hectare and at this level yield of 1.30 ton per hectare was obtained with eight irrigations. However, they did not notice significant influence of phosphorus on seed yield.

per hectare. Phosphorus and potassium application significantly reduced the days taken to various developmental stages. However, a dose of 50 kg N + 60 Kg P_2O_5 + 60 Kg K_2O per hectare was found optimum for sunflower. Hanumantha Rao and Dyasagar (1981) observed that application of nitrogen alone and in combination with P or K fertilizer increased the growth and growth components of sunflower. However, the effect of N was more in the presence of P. Potassium did not influence plant height and relative growth rate but increased other biometric parameters, yield and yield attributes.

Nazir *et al.* (1987) reported that N,P and K had no significant effect on plant number per m^2, while plant height was greatest with 75 N kg per hectare (202 cm). The root CEC, root length and dry weight were increased linearly with P application (Naphade and Naphade, 1991). Ramamurthy and Shivashankar (1995) obtained significantly higher dry matter production of sunflower at 56.25 kg P_2O_5 per hectare (37.90 g/plant)over 37.5 kg P_2O_5 per hectare (36.10 g/plant).

Application of phosphorus at the rate of 100 kg P_2O_5 per hectare recorded significantly higher dry matter production, LAI, NAR and RGR. At 30 DAS application of phosphorus at 100 kg P_2O_5 per hectare increased the dry matter production per plant by 17 per cent (6.65 g/plant) when compared to 75 kg P_2O_5 per hectare (6.35 g/plant). Similar trend was observed at 60 DAS and at physiological maturity (Shivaprasad *et al.*, 1996).

Vasudevan *et al.* (1997) revealed that application of 60:79.2:50.4 NPK kg per hectare significantly increased the leaf area index and shoot length of 3.38 and 21.8 cm respectively at 60 DAS when compared to application of 60:39.6:50.4 NPK kg per hectare which recorded a LAI and shoot length of 3.14 and 20.5 cm respectively.

2.1.2 Yield components, yield and oil content

Mukundan (1972) reported that phosphorus application significantly influenced the seed yield and yield components like head diameter, number of seeds per head and 1000-seed weight. Gaur et al. (1973) reported that the seed yield increased progressively with increasing levels of phosphorus, and same trend was

Aulakh *et al.* (1990) reported that sunflower hybrid MSFH-1 gave highest seed yield of 2.84 tonnes per hectare with 60:30 NP kg per hectare and reduced to 2.10 ton per hectare under control. Nayak and Ghose (1990) found that the sunflower varieties viz., Cv. EC-68414 and Surya gave maximum yield at 60 kg P_2O_5 per hectare, while the seed yield of morden declined beyond 30 kg P_2O_5 per hectare. Harmati (1990) found that application of nitrogen at 150 kg per hectare slightly increased the seed yield, oil content and oil yield of sunflower.

Ujjinaiah *et al.* (1993) studied the effect of nitrogen on sunflower and revealed that application of 45 kg N per hectare recorded highest oil content (41.8%) over application of 60 or 75 kg N per hectare Hiremath *et al.* (1991) noticed that oil content of BSH-1 sunflower was highest with 40 kg N per hectare and increased with increasing levels of phosphorus upto 100 kg per hectare.

Shumba *et al.* (1991) found that application of 30 kg N per hectare increased seed yield by 26 per cent over control. Further, increase in N levels increased the yields slightly and was considered uneconomical. Sidhu *et al.* (1991) observed that the crop did not respond to phosphorus in any of the locations or cropping systems. However, they found decreased oil content with nitrogen and increased oil content with phosphorus application.

Gangadhar *et al.* (1992) obtained the highest seed yield (1.92 t/ha) of sunflower with 37.5 kg N + 50 kg P + 39.5 kg K and 50 kg FeSo4 per hectare compared to control which recorded a seed yield of 0.90 ton per hectare. Sirbu and Ailincai (1992) found that application of 80 kg N + 80 kg P_2O_5 + 80 kg K_2O per hectare produced the highest seed yield of 3.50 tonnes per hectare. Kharchenko and Hartchenko (1992) reported increased sunflower seed yield by 0.2 ton per hectare with application of 90:90:90 kg NPK per hectare that with of 45:45:45 kg NPK per hectare.

Megur *et al.* (1993) observed increased grain yields and 1000-seed weight of sunflower with 90 kg N and 120 kg P per hectare. Further, increase in N level to 120 kg per hectare decreased the grain yield. Increase in grain yield was 2.80 and 5.82 q per hectare as N application increased from 30 to 60 and 60 to 90 kg per hectare respectively. The increase in grain yield with P application was 1.36, 1.14 and 1.13 q per hectare when P application increased from 30 to 60, 60 to and 90 to 120 kg P_2O_5, respectively.

Mohammed *et al.* (1993) obtained significant increase in seed yield of sunflower with the application of 90 kg P_2O_5 per hectare (12.5 q/ha) when compared to control (9.64 q/ha). Khokani et al. (1993) didnot observed significant difference in grain yield due to application of nitrogen between 60 and 90 kg per hectare and these inturn were significantly superior to control.

Prabhuraj *et al.* (1993) observed significant increase in seed and oil yield of sunflower with application of 112.5 kg P + 5 kg Zn per hectare compared to control. Further, they have reported that the seed yield of sunflower increased from 1780 to 2829 kg per hectare and oil yield from 635.5 to 1131 kg per hectare due to application of 112.5 P_2O_5 and 5 kg Zn per hectare over control.

Ujjinaiah *et al.* (1993) obtained on par seed yield (825 kg/ha) between application of 50 per cent RDF (20:25:20 kg NPK /ha) and 100 per cent RDF (40:50:40 kg/ha NPK) and concluded that application of only 50 per cent RDF is economical. Annadurai and Palaniappan (1994) reported that application of 40 kg P_2O_5 and 40 kg K_2O per hectare increased the seed yield (1459 kg/ha) and oil content (44.3%) of sunflower significantly over unfertilized control.

Sathiyavelu *et al.* (1994) obtained significant increase in sunflower yield with increasing levels of N, P and K under rainfed condition. Application of N at 60 kg N per hectare recorded highest seed yield of 737 kg per hectare over application of 50 kg N per hectare (694 kg/ha). Highest seed yield was noticed with application of 60 kg P_2O_5 per hectare (757 kg/ha) followed by 40 kg P_2O_5 per hectare (673 kg/ha). Application of 40 kg K_2O per hectare produced higher seed yield (716 kg/ha) compared to application of 20 kg K_2O per hectare (600 kg/ha).

Manoharan *et al.* (1994) observed that application of N at 60 kg per hectare increased the seed yield and oil content of sunflower significantly (2200 kg/ha and 45.9% respectively) when compared to application of 20 kg N per hectare (1600 kg/ha and 42.7% respectively). Further, increase in the nitrogen level reduced the yield and oil percentage.

Kulmi and Soni (1995) found increased seed yield of sunflower (Cv. morden) with increasing levels of NPK fertilizer from 20:20:10 kg NPK per hectare to 60:30:30 kg NPK per hectare. Mishra et al. (1995) obtained significantly higher seed yield of sunflower with 60 kg N and 60 kg P_2O_5 per hectare. Application of 60 kg N per hectare recorded a seed yield of 9.20 q per hectare. The seed yield obtained with 60 kg P_2O_5 per hectare (8.66 q/ha) was 8.5 and 3 per cent higher than that with 20 and 40 kg P_2O_5 per hectare respectively.

Shivaprasad *et al.* (1996) reported that application of phosphorus at the rate of 125 kg per hectare produced significantly higher seed yield of sunflower (1084.24 kg/ha) compared to application of 75 kg per hectare (947.33 kg/ha). However, seed yield obtained by 100 kg P_2O_5(1047.03 kg/ha) was on par with the application of 125 kg P_2O_5 er hectare. Bahl *et al.* (1997) revealed that application of 30 kg N and 60 kg P significantly increased the sunflower seed yield and oil content (31.85 q/ha and 43%) over unfertilized control which recorded a seed yield and oil content of 20.80 q per hectare and 39.2 per cent respectively.

2.1.3 Nitrogen, phosphorus and potassium content and uptake by sunflower

Kalra and Tripathi (1980) observed that application of 20 kg N per hectare increased the uptake of N(129.2 kg/ha), P(32.80 kg/ha) and K (76.94 kg/ha) when compared to lower dose of N(40 or 80 kg N/ha). Similarly application of phosphorus at 120 kg per hectare increased the uptake of N(96.58 kg/ha), P(27.51 kg/ha) and K (63.90 kg/ha) as compared to 60 kg P per hectare.

Nitrogen uptake in sunflower seeds increased with application of N, K and molybdenum. Total N and K uptake by seeds were significantly increased by soil application of K + molybdenum(Samui and Bhattacharyya, 1987). Narem *et al.* (1981) reported that 80-95 per cent of P was taken up at the time of anthesis and subsequently translocation to developing seeds occured first from the stems and petioles and latter from leaves and receptacles.

Loubser and Human (1983) observed that critical P-percentage (P concentration required to sustain 90 per cent of maximum yields) was 0.27 and 0.24 per cent in Cv. Kortas and S-230 respectively. Sarkar(1985) found that graded levels of N, from 0 to 80 kg per hectare increased seed yield and N, P and K content in sunflower grown on acid laterite sandy loam soil (pH 5.6). Application of 80 kg N per hectare recorded 1.24, 0.5 and 2.96 per cent N, P and K content respectively.

Kadar and Vass (1986) revealed that 0.25 to 0.30 per cent was the optimum P content in shoot at 4-6 leaf stage. Samui and Bhattacharyya (1987) observed that application of N, P and K alone or in combination, significantly increased the uptake of NPK in sunflower. The uptake was 148:29.6:243.8 kg per hectare with application of 60:40:40 kg per hectare and was significantly higher than unfertilized control, where the uptake was 62.2 N, 11.7 P and 74.9 K kg per hectare.

Hiremath *et al.* (1992) reported that application of N at 80 kg per hectare significantly increased the N(63.74 kg/ha) and P(8.53 kg/ha) uptake when compared to application of 40 kg N per hectare (54.98 and 7.51 kg/ha). Application of phosphorus at 100 kg per hectare increased the uptake of N(54.33 kg/ha) and P (8.13 kg/ha) over lower doses of phosphorus (0-50 kg P_2O_5/ha).

Ortiz and Bastidas (1992) reported that highest N content (3.19%) occured in the leaves at 40 days after emergence and highest `K' content (5.4%) in stem at 40 days after emergence. After 80 days, uptake of N, P and K by sunflower reached 69.9, 16.7 and 166.2 kg per hectare respectively. Khokhani *et al.* (1993) found increased NPK content and uptake in seeds with 60 kg N per hectare application. Annaduri and Palaniappan (1994) reported that application of 40 kg P_2O_5 and 40 kg K_2O per hectare significantly increased the N(52.6 kg/ha), P(18.8 kg/ha) and K(46.3 kg/ha) uptake when compared to unfertilized control (48.2, 7.1 and 34.2 kg NPK per hectare. respectively).

Manoharan *et al.* (1994) revealed that uptake of N, P and K was 72.39, 10.8 and 138.4 kg per hectare respectively with application of 50 kg N per hectare which was significantly superior over 40 kg N per hectare. Mishra *et al.* (1995) noticed increased uptake of NPK in sunflower with increasing levels of N and P from 20 to 60 kg per hectare. Application of 60 kg N per hectare recorded significantly higher uptake of 66.4, 30.4 and 54.7 kg NPK per hectare while application of 60 kg P_2O_5 per hectare recorded uptake of 58.8, 30.7 and 48.1 kg NPK per hectare. Shivaprasad et al. (1996) reported that, among the phosphorus levels, application of 125 kg P_2O_5 per hectare increased the P uptake significantly (12.81 kg/ha) followed by 100 kg P_2O_5 per hectare (12.27 kg/ha).

Bahl *et al.* (1997) observed that application of N and P at 60 kg per hectare significantly increased the uptake of NPK in sunflower were 118.7, 15.1 and 17 kg NPK per hectare respectively over 30 or 90 or unfertilized control kg per hectare..

2.2 *EFFECT OF FYM ON CROP PLANTS*

The farm yard manure seems to act directly in increasing crop yields either by acceleration of respiratory process by increasing cell permeability, by harmone growth action or by combination of all these processes. It supplies nitrogen, phosphorus and sulphur in available form to the plants through biological decomposition. Indirectly it improves physical properties of soil such as aggregation, aeration, permeability and water holding capacity.

2.2.1 *Effect of farm yard manure on growth, yield components and yield of sunflower*

Lasho and Agaraj (1982) reported that application of farm yard manure @ 20 ton per hectare along with 400 kg superphosphate + 200 kg ammonium nitrate per hectare increased the sunflower seed yield by 30.1 per cent over control, while application of 20 ton FYM alone increased sunflower seed yield by 21.0 per cent over control. Matherl and Stewart (1982) obtained maximum yield of sunflower (2.85 t/ha) with application of 84 kg N per hectare and 45 ton FYM per hectare. They also found that 45 ton per hectare FYM had supplied some needed elements which are not supplied by inorganic nitrogen. An experiment conducted at Philippines revealed that height of plant at maturity, head diameter, 1000-seed weight and yield of sunflower were significantly influenced by application of farm yard manure with supplemental inorganic fertilizer. The highest yield of sunflower (1122.22 kg/ha) was obtained in the treatment receiving 10 tons FYM and 120:60:0 kg NPK per hectare (Alimurong, 1984).

Govi *et al.* (1988) observed significant increase in grain yield of sunflower with application of 10 tonnes per hectare farm yard manure in combination with 40 kg N + 30 kg P_2O_5 per hectare under rainfed condition. Radia *et al.* (1988) found that application of cowdung increased the seed yield(2.9 t/ha), 1000 seed weight(62 g) and seed oil content(46%) in sunflower compared to application of cotton waste compost. Agasimani and Hosamani (1995) reported that application of 7.5 ton FYM per hectare increased the groundnut pod yield (2417 kg/ha) and also yield components compared to no FYM application.

Awad and Geeresh (1992) obtained highest sunflower seed yield (26.36 q/ha) with the application of 20 ton per hectare organic manure + 190 kg N per hectare. Ram et al. (1992) noticed highest seed yield of sunflower (0.7 t/ha) with application of FYM @ 10 tonnes per hectare in combination with 40:30:20 NPK kg per hectare. Sathiyavelu *et al.* (1994) observed that application of FYM at 10 ton per hectare with recommended dose of fertilizers 50:60:40 kg NPK per hectare was found optimum to get economic yield in sunflower under rainfed condition in Coimbatore region.

Ramamurthy and Sivashankar (1995) reported that sunflower seed yield (1217 kg/ha) was increased by 28 per cent by residual effect of organic matter applied @ 10 tonnes per hectare when compared to application of only 5 ton per hectare of organic matter (1099 kg/ha).

The studies conducted at Akola during *rabi* season of 1994, showed that the application of FYM @ 5 ton per hectare as band placement significantly increased sunflower seed yield (1350 kg/ha) over control which recorded an yield of 911 kg per hectare. The per cent increase in yield over control with FYM @ 5 tonnes per hectare was 37 per cent(Anon, 1995a).

Similarly the studies conducted at Akola during 1994 *rabi*, revealed that application of recommended dose of manures (5 t FYM) and fertilizers (60:90:40 NPK kg/ha) along with borax and $ZnSO_4$ spray recorded significantly higher seed yield (705 kg/ha) than only with RDF and RDM (605 kg/ha) (Anon. 1995 b). Patil *et al.* (1996) found that application of FYM @ 20 tonnes per hectare significantly increased the yield of sunflower (13.9 q/ha) when compared to control (12.7 q/ha). Tashilkar and Chavan (1996) reported that application of N and P in combination with FYM increased the pod yield of groundnut significantly by 17 per cent over control (No fertilizer, no FYM).

2.3 EFFECT OF VERMICOMPOST ON CROP PLANTS

Vermicompost is an aerobically degraded organic matter which has undergone chemical disintegration by the enzymatic activity in the gut of worms and so also enzymes of the associated microbial population (Kale *et al.* 1992). Vermicompost contain considerable amount of plant nutrients in the available form. The agricultural importance of vermicompost was first reported by Hopp and Slater (1949). Further, they quantified the response of crop to earthworms in terms of yield. Subsequently its positive effect on crop growth was studied by many scientists. Field studies on the effect of vermicompost on sunflower and other oilseed crops are meagre. Hence, studies on the effect of vermicompost on other field crops is also reviewed here.

2.3.1 Effect of vermicompost on growth, yield components and yield

Significantly increased plant height, number of leaves, total dry matter and grain yield was observed in wheat with application of worm cast (Nijhawan and Kanwar, 1952). Several studies indicated increased yield in barley with use of vermicompost (Atlavinyte *et al.* 1968, Edwards and Lofty, 1978).

Krishnamoorthy and Varanabhaiah (1986) reported the influence of worm cast to wheat increased the dry matter of leaf (Saciragic and Dzelilovic, 1986). In a study conducted by Kale and Banokubra (1986) in summer Paddy (IR-20) it was found that the vegetative parameter like shoot weight, root weight, root and shoot length were positively influenced due to application of worm cast than with chemical fertilizer.

Savalagi and Savalagi (1991) found increased germination percentage, shoot length and dry matter of hybrid sorghum (CSH-5) by treating seeds sorghum with worm cast. In sunflower the weight of seeds increased significantly with the application of vermicompost over other treatments (Kale et al. 1992).

Hapse (1993) concluded that application of vermicompost @ 5 ton per hectare to sugarcane (Cv. Co 7219) increased the cane yield by 12.7 per cent and sugar recovery by 0.92 per cent as compared to application of only chemical fertilizer. In sunflower (CV EC 68415 and Morden) Kale et al. (1994) obtained increased seed yield by the application of either 50 per cent vermicompost with 50 per cent recommended dose of fertilizer or full dose of FYM and vermicompost.

Stephens *et al.* (1994) observed increased shoot and root dry weight of wheat plants in the presence of earthworms. In groundnut, vermicompost or in situ vermiculture increased the pod yield by about 10 per cent (Agasimani and Hosamani, 1995). In sorghum recommended dose of fertilizer along with 2.5 ton per hectare vermicompost and 10 kg per hectare azospirillum increased the production.(Krishnamurthy *et al.* 1995).

The studies conducted at Coimbatore during 1995 kharif showed that vermicompost @ 2 ton per hectare as basal application in seed rows recorded highest seed yield of 984 kg per hectare in sunflower which was significantly superior over the yield obtained with FYM @ 5 ton per hectare (722 kg/ha) and control (592 kg/ha). Further, application of vermicompost with full recommended dose of fertilizers recorded the highest yield of 1287 kg per hectare and vermicompost with 50 per cent recommended dose of fertilizer significantly yielded higher yield (1081 kg/ha) compared to yield (812 kg/ha) obtained with only full recommended dose of fertilizer (Venkatakrishnan and Balsubramaniam, 1996)

Studies conducted at Akola during *rabi* season revealed that application of organic manures namely FYM @ 5 ton per hectare and vermicompost @ 2 ton per hectare recorded statistically on par yield (1350 and 1307 kg/ha respectively) and inturn both these treatments were significantly superior over control which recorded an yield of 911 kg per hectare (Anon. 1995-56 a).

Sarwad *et al.* (1996) revealed that application of RDF and vermicompost (1 t/ha) with 50 or 75 per cent RDF recorded on par grain yield of sorghum. They also noticed improved physical properties of vertisol with vermicompost as compared to only fertilizer application.

Shivanand *et al.* (1996) obtained highest uptake of sulphur in plants in treatments with farmyard manure treated soils (1425 mg/pot) followed by vermicompost (944 mg/pot) and control (853 mg/pot) at harvest in french bean. Residual availability of sulphur (ppm) was highest in vermicompost treated soil (402 mg/pot) at flowering stage and at harvest (425 mg/pot) compared to farmyard manure treated soil.

2.4 EFFECT OF PHOSPHORUS SOLUBILISING MICRO ORGANISMS ON CROP PLANTS

Bacterial fertilizers constitute one of the most widely used achievements of Agricultural microbiology. The use of bacterial fertilizers when applied singly or in combination with various fertilizers and manures is claimed to increase crop yield. Phosphobacterin has been reported to increase the yields of cereals by 15 to 20 per cent. Phosphate solubilising bacteria(PSM) will help in solubilising the fixed phosphorus by producing the phytase enzyme. Response of sunflower crop to inoculation with PSM is limited. Hence, the inoculation influence in other crops is also reviewed briefly here.

2.4.1 Effect of phosphorus solubilising micro organisms on growth, yield components and yield

Gerreston (1948) for the first time obtained conclusive evidence that plants like oats, mustard etc., supplied with insoluble phosphate such as Algeran phosphate, bonemeal, tri and di calcium phosphate etc, gave improved growth and increased phosphate uptake varying from 16 to 54 per cent, when inoculated with P-solubilising microorganisms when compared to the plants grown under sterile condition. This was supported by the findings of Pikovskaya (1948) and Dorosinky and Lazarev (1949). Fielder and John - Deeshach (1956) in field and pot experiments with phosphobacterin found non significant increase in dry matter production of various plants as a result of inoculation of Chernozymes and humus loam soil with phosphobacterin.

Sundara Rao and Paul (1959) conducted experiments on berseem and wheat, using Fosfo-24 (a czechoslovakin culture). Significant increase in P-uptake over control was recorded . The increase in yield varied between 10 to 20 per cent in berseam and 7 to 33 per cent in wheat.

Cantir *et al.* (1962) reported that, inoculation of unfertilized soil with nitrogen, phosphobacterin and azotobacter increased the yields of soybean upto 7 per cent and that with silicobacterin upto 4 per cent. Phosphobacterin and silicobacterin inoculated to fertilized soil increased yields upto 10 per cent.

Smatsevich (1962) observed that, the effectiveness of bacterial fertilizers was due to the synthesis of growth promoting substances and not to specific improvement in the supply of N, P and K to the plants. Ahmad and Jha (1982) revealed that inoculation of *B. megaterium* with 60 kg P_2O_5 per hectare as single super phosphate significantly increased the dry matter (6.1 g/plot) and P-uptake (25.3 mg p/pot) compared to uninoculated control (5.7 g/pot and 24.7 mg/pot respectively).

A significant increase in the yield of wheat crop was obtained when rock phosphate was applied to soil and the seeds were inoculated with *Pseudomonas* *striata* The response in grain yield was equivalent to the application of 50 kg P_2O_5 per hectare, in form of super phosphate (Gaur *et al.*, 1980).

Hebbara (1987) in field trial on coastal acid soil of Dakshina Kannada district observed that, application of 150 kg Mussoorie rock phosphate(MRP) per hectare in combination with FYM and phosphate solubilising bacteria or super phosphate + FYM performed significantly better than other treatments with respect to yield and nutrient uptake by groundnut. Tiwari *et al.* (1989) reported that seed inoculation with *Bacillus polymyxa* markedly increased the yield of rice and chickpea while *Pseudomonas striata* increased the yield in wheat with super phosphate or rock phosphate.

In soybean highest yield of 26.64 q per hectare was recorded when seed inoculation of microphos was done in combination with 50 per cent mussoorie rock phosphate and 50 per cent single super phosphate. But this was on par with soil inoculation of phosphin alone (Patil, 1990). Mohod *et al.* (1989) found that inoculation of P-solubilising organism (*Pseudomonas striata* and *Bacillus polymyxa* along with 50 kg P as single super phosphate significantly increased the P-uptake (10.52 kg/ha) when compared to control (5.35 kg/ha). Available phosphorus in root zone of rice crop at maturity was markedly increased with inoculation of P-solubilizer (28.05 kg/ha) over application of only 50 kg p per hectare (26.95 kg/ha).

Rachewad *et al.*(1992) reported that application of single super phosphate at the rate of 60 kg P_2O_5 per hectare along with inoculation of *Bacillus megaterium* var. phosphaticum produced highest dry matter (5.40 g/plant) phosphorus content (0.54%) and P-uptake (29.04 mg/plant) over application of 60 kg P_2O_5 per hectare alone.

Tippannavar *et al.* (1992) obtained increased grain yield of Sorghum and gram (1720 and 1490 kg/ha respectively) with the application of P-solubilizers and 40 kg N + 60 Kg P per hectare for sorghum and 12.5 kg N + 25 kg p per hectare for gram over uninoculated control (1450 and 1300 kg/ha respectively).

Jones and Sreenivas (1993) studied the response of sunflower to the inoculation of *Pseudomonas striata* and *Glomus fasiculatum* at four levels of two forms of phosphorus in black clayey soil. The results indicated that inoculation of *Pseudomonas striata* + *Glomus fasiculatum* in conjunction with 100 per cent RDP as super phosphate (2344 mg/pot) significantly increased the seed yield of sunflower (25.79 g/plant) and shoot p concentration 0.27 per cent over uninoculated control treatment (16.89/plant and 0.13% P respectively). Inoculation of *Pseudomonas striata* with 37.5 kg MRP + 12.5kg SSP per hectare recorded significantly higher pod yield of groundnut (50.69 q/ha) when compared with 37.5 kg SSP + 12.5 kg MRP per hectare applied alone which recorded a yield of 40.4 kg per hectare (Mudalagiriyappa 1993).

Tomar *et al.* (1993) reported that application of phosphate solubilising bacteria significantly increased the seed yield of black gram (9.03 q/ha) over uninoculated control (7.39 q/ha). The per cent increase in seed yield was 22.5 over control. Application of vermicompost @ 2 ton per hectare + 50 per cent RDF + PSM recorded on par yield of sunflower (1179 kg/ha) compared to application of 100 per cent RDF (1138 kg/ha). The results revealed that application of PSM + Vermicompost can substitute 50 per cent of chemical fertilizers (Anon. 1996 b).

Manjaiah *et al.* (1996) revealed that combined application of FYM and P-solubilizers along with MRP significantly increased the dry matter accumulation and pod yield of groundnut (51.89 g / plant and 19.80 q/ha) over mussoorie rock phosphate (MRP) alone (41 g/plant and 16.01 q/ha respectively).

Material and Methods

III. MATERIAL AND METHODS

A field experiment was conducted to study the effect of different organic manures, biofertilizer and fertilizer levels on growth, yield components, yield and oil content of sunflower (Cv. CMS 234B) at Agricultural College farm, Raichur during *rabi/summer* season of 1996, under irrigation. The details of the materials used and the techniques adopted during the course of investigation are described below.

3.1 EXPERIMENTAL SITE

The experiment was conducted at Regional Research Station, Raichur in D-block during *rabi*-1996. Raichur is situated in the North-Eastern dry zone (Zone-2) of Karnataka between 16° 15'N latitude and 77° 20'E longitude and at an altitude of 389 meters above the mean sea level.

3.2 SOIL CHARACTERS OF EXPERIMENTAL SITE

The soil of the experimental site was red sandy loam in nature. Composite soil sample from 0-30 cm depth was collected from the experimental area before sowing and analysed for chemical characteristics. The values obtained along with methods employed are presented in Table 1.

3.3 CLIMATIC CONDITIONS

The data on climatic parameters, recorded at the meteorological observatory, Regional Research Station, Raichur are presented in Table 2 and depicted in Figure 1 and 2.

The average annual rainfall of 60 years was 678.80 mm. September month received the mean maximum rainfall of 154.50 mm. April and May are the hottest months having mean maximum temperature of 39.70 °C while, December and January are the coldest months with mean month minimum temperature varying from 16 to 16.4 °C. The relative humidity fluctuate between 51.50 per cent during April and 83.00 per cent during August.

Table 1: Physical and chemical properties of the experimental site

Sl No.	Particulars	Values obtained	Method adopted
I.	Physical properties		
	1. Particle size analysis		
	a. Sand (%)	55.42	International Pipette method (Piper, 1966)
	b. Silt (%)	19.48	International Pipette method (Piper, 1966)
	c. Clay (%)	23.10	International Pipette method (Piper, 1966)
	2. Bulk density (g/cc)	1.52	Core sampler method (Dastane, 1967)
II.	Chemical properties		
	1. Soil reaction (pH)	7.32	Blackman's pH meter (Jackson, 1967)
	2. Electrical conductivity(dsm^{-1})	0.12	Elico solo bridge
	3. Organic carbon(%)	0.61	Wet oxidation method (Jackson, 1967)
	4. Available nitrogen (kg/ha)	198.57	Alkaline permanganate method (Subbaiah and Asija, 1956)
	5. Available phosphorus (kg/ha)	31.48	Olsen's method (Muhr et al., 1965)
	6. Available potassium (kg/ha)	229.58	Flame photometer (Muhr et al ., 1965)

Table 2: Mean monthly meteorological data for the year 1996-97 and average of 66 years recorded at the meteorological observatory of the Regional Research Station, Raichur

Months	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
			Maximum		Minimum			
	1930-96	1996-97	1930-96	1996-97	1930-96	1996-97	1930-96	1996-97
March	6.30	0.0	30.80	38.40	30.70	22.20	53.90	40.50
April	18.20	20.20	39.70	39.60	23.50	24.60	50.50	46.20
May	34.40	14.80	34.40	41.90	24.60	25.90	61.00	35.50
June	95.50	310.70	35.50	35.40	23.00	23.20	75.30	63.00
July	112.10	72.80	32.80	35.50	22.00	22.00	81.20	64.00
August	129.40	250.20	32.10	31.50	21.80	22.60	83.00	75.10
Sept	154.50	122.80	32.60	31.60	21.20	21.50	82.20	74.00
Oct	91.70	176.00	32.10	30.90	90.20	17.80	75.60	72.50
Nov	24.40	11.80	30.70	31.50	17.30	15.80	75.10	63.00
Dec	8.30	5.80	29.50	30.30	16.00	16.50	76.60	60.40
Jan	1.60	5.00	30.20	30.20	16.40	15.30	74.70	60.30
Feb	2.40	0.00	34.80	34.40	19.20	17.60	58.40	40.60

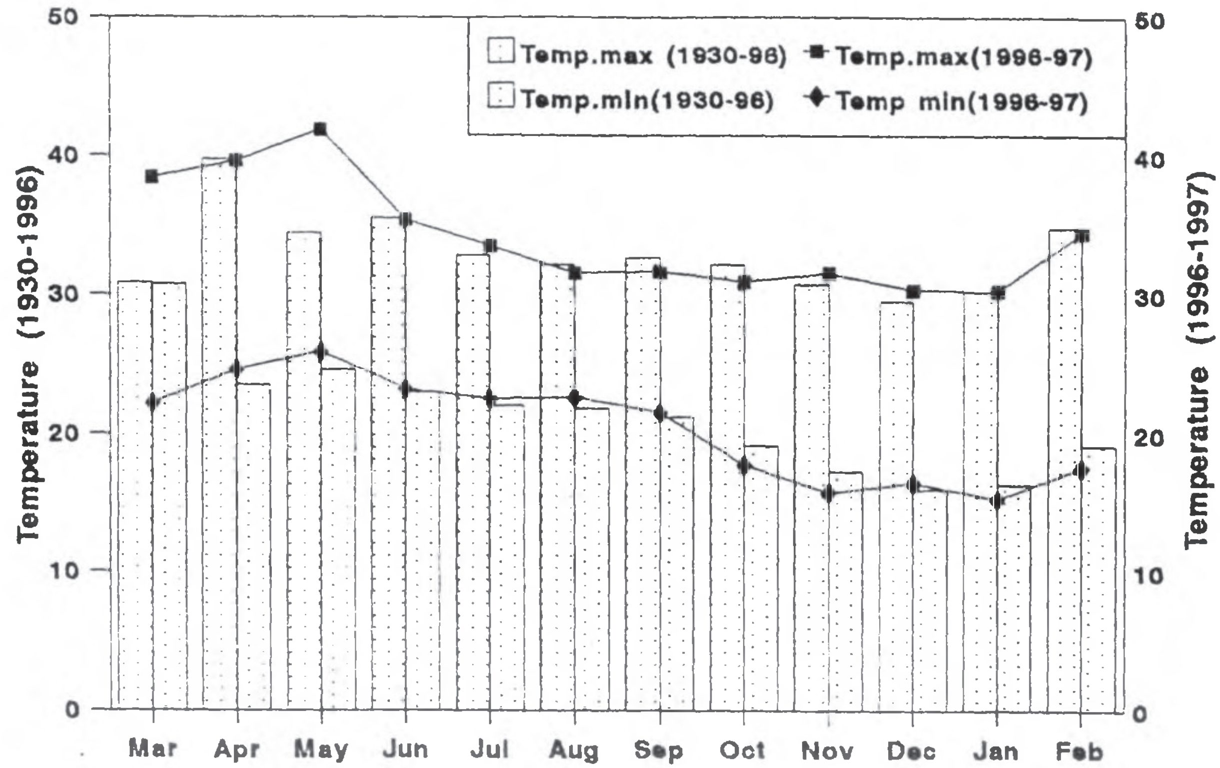

Fig. 1. Mean temperature (Max. and Min.) recorded during 1930-1996 and 1996-1997 at RRS, Raichur

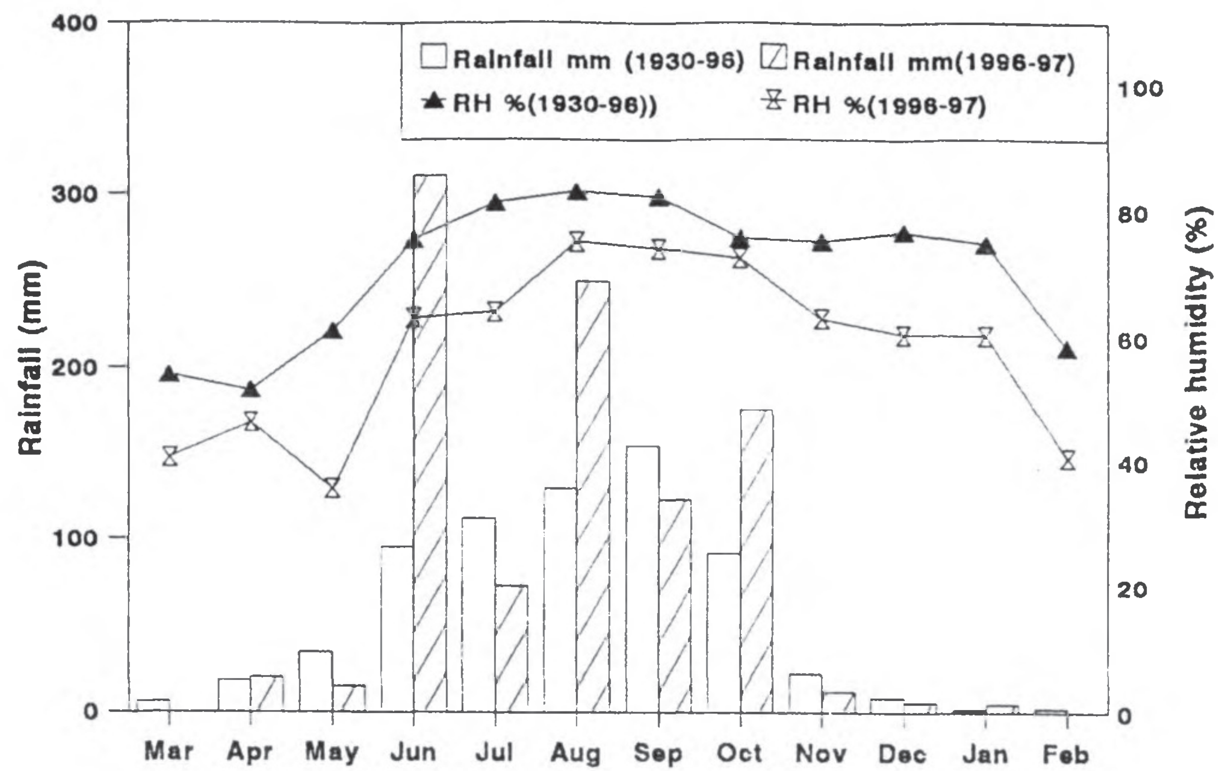

Fig. 1.Mean rainfall and relative humidity recorded during 1930- 1996 and 1996-1997 at RRS,Raichur

3.4.1.2 Plot size

Gross plot : 4.2 m x 5.0 m

Net plot : 1.8 m x 4.2 m

3.5 CULTURAL OPERATIONS

3.5.1 Land preparation

The land was prepared by ploughing once with wooden plough followed by three harrowings to bring the soil to fine tilth and then ridges and furrows were formed at 60 cm apart. Farm yard manure was applied 15 days before sowing and vermicompost was applied on the day of sowing to the respective plots as per the treatments.

3.5.2 Fertilizer application

Nitrogen, Phosphorus and potassium were applied on 7th November 1996 in the form of urea, DAP and muriate of potash respectively. The entire dose of phosphorus and potassium and 50 per cent of nitrogen were placed 5 cm deep and 5 cm away from the row at sowing as basal dose. Remaining 50 per cent nitrogen was applied at 45 days after sowing.

3.5.3 Seeds and sowing

The seeds of sunflower Cv. CMS 234 B were treated with phosphate solubilizing micro-organisms as per the treatment. The lignite based culture of *Pseudomonas striata*, was obtained from the Department of Agricultural Microbiology, UAS, Dharwad. The seeds were dibbled on 7th November 1996 by giving a spacing of 60 cm between the rows and 20 cm between the seeds within the row.

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

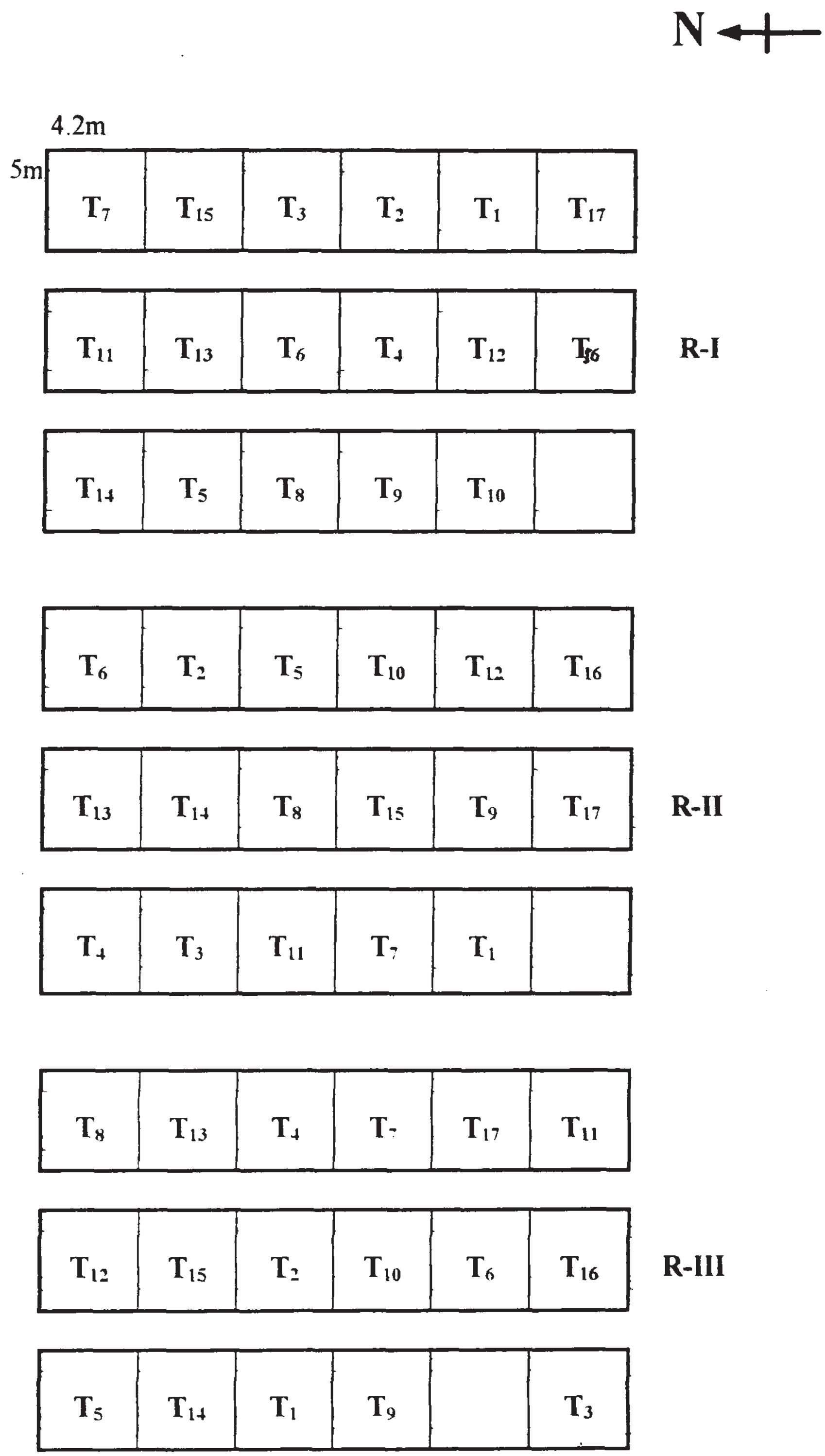

Fig. 3 PLAN OF LAYOUT

3.4 EXPERIMENTAL DETAILS

3.4.1 Design and layout

The field experiment was laid out in a randomized block design with 17 treatments and replicated three times. The plan of layout of the experiment is given in Figure 3.

3.4.1.1 Treatments

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

3.5.4 Irrigation

Soon after sowing, first irrigation was given with 5 cm depth of water. Subsequent irrigations were given as and when required. Total 10 irrigations were given from sowing to harvest.

3.5.5. After care

Five days after sowing, gap filling was done to ensure uniform plant population. Thinning was done later to maintain one plant per hill. Inter cultivation with entire blade hoe was done at 20th and 45th days after sowing. Hand weeding was done twice to remove the left over weeds.

3.6 HARVESTING AND THRESHING

The sunflower crop was harvested on 12th February 1997 when the crop attained full maturity as indicated by yellow colour on the backside of head. The heads from the net plot were cut, air dried, threshed and the seed yield per plot was recorded. The stalks were cut at the ground level and were left in the field for drying. The weight of the stalk per plot was recorded after complete drying.

3.7 COLLECTION OF EXPERIMENTAL DATA

3.7.1 Preharvest observation

Five plants per plot were selected randomly in the net plot and tagged for recording observations at three stages (30th, 60th day after sowing and at harvest).

3.7.2 Plant height

The height of five plants was measured from the ground level to the growing tip of the plant and the average height was expressed in centimeter.

3.7.3 Leaf area per plant (cm^2)

Leaf area per plant was measured by using leaf area meter.

3.7.4 Leaf area index (LAI)

Leaf area index is defined as leaf area (assimilatory source) per unit land area. It was calculated by dividing the leaf area per plant by the land area occupied by a single plant (Sestack *et al.*, 1971)

$$LAI = \frac{A}{P}$$

Where; LAI = Leaf area index
P = Unit land area
A = Leaf area

3.7.5 Leaf area duration (LAD)

Leaf area duration is the integral of LAI over the growth period and was worked out as per the formula given by Power *et al.* (1967).

$$LAD = \frac{L_i + (L_{i+1})}{2} \times (t_2 - t_1)$$

Where; L_i = Leaf area index at i^{th} stage
L_{i+1} = Leaf area index $(i+1)^{th}$ stage
$(t_2 - t_1)$ = Time interval between ith and $(i+1)^{th}$ stage in days.

3.7.6 Dry matter production and accumulation in different plant parts

Dry matter production and its distribution in stem, leaf and head was recorded at the three crop growth stages. Each of the five plants uprooted were separated into leaf, stem and head and dried in an oven at 65 to 70°C to constant weight and the oven dry weight was recorded. The average of five plants was taken as dry matter production in different plant parts per plant. The sum of mean dry weight of all the plant parts was taken as the total dry weight per plant and was expressed in g per plant.

3.7.7 Rate of dry matter accumulation

This was estimated by dividing the difference in the total dry weight of plant at two stages by the interval between those two stages and was expressed as g per plant per day.

$$\text{Rate of dry matter accumulation} = \frac{W_2 - W_1}{t_2 - t_1}$$

where, W_1 = Dry weight of the plant in g at time t_1

W_2 = Dry weight of the plant in g at time t_2

$t_2 - t_1$ = Time interval between i^{th} and $(i+1)^{th}$ stage in days.

3.7.8 Relative growth rate (RGR)

It is the rate of increase in dry weight per unit dry weight of the plant per unit time and is expressed as g per g per day. It was calculated by the formula proposed by Radford (1967).

$$RGR = \frac{\text{Log}_e W_2 - \log_e W_1}{t_2 - t_1}$$

where,

RGR = Relative growth rate (g/g/day)

W_1 and W_2 = Plant dry weight (g) at time t_1 and t_2, respectively.

$t_2 - t_1$ = Time interval (days)

Log_e = Logarithm to the base e (Neperian constants)

3.7.9 Net Assimilation rate (NAR)

Net assimilation rate is the rate of increase in dry weight per unit leaf area per unit time (Watson, 1952) and was expressed as g per dm^2 per day. It was calculated by applying formula suggested by Gregory (1926).

$$NAR = \frac{(W_2 - W_1)(Log_e L_2 - Log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

where,

NAR = Net assimilation rate ($g/dm^2/day$)

L_1 and W_1 = Leaf area in cm^2 and dry weight of the plant in g at time t_1 respectively

L_2 and W_2 = Leaf area in cm^2 and dry weight of the plant in g at time t_2 respectively.

t_1 and t_2 = Time interval (days)

Log_e = Logarithm to the base e (Neperian constant)

3.7.10 Crop Growth Rate (CGR)

It is defined as the rate of dry matter production per unit time. It was worked out by using formula proposed by Watson (1952) and is expressed as g per dm^2 per day

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{p}$$

Where,

CGR = Crop growth rate ($g/dm^2/day$)

W_1 and W_2 = Dry matter production per plant(g) at time t_1 and t_2 respectively

P = Ground area covered by plant (dm^2)

3.8 OBSERVATIONS ON YIELD AND YIELD COMPONENTS

The heads from the randomly selected tagged five plants for taking biometric observation at harvest were used and the following observations on the yield and yield components were recorded.

3.8.1 Diameter of the head (cm)

The distance between the two diagonally opposite edges of the head and was recorded in cm.

3.8.2 Thousand seed weight

Thousand seeds were counted from seed, sample drawn from each net plot seed yield. The weight of thousand seed was recorded in g.

3.8.3 Total number of seeds per head

The seeds obtained from each head of the five sample plants were cleaned and separated into filled and unfilled seeds. Filled and unfilled seeds per head were counted separately. The sum of these two types of seeds was taken as total number of grains per head.

3.8.4 Number of filled seeds per plant

The mean number of filled seeds per head was counted and recorded.

3.8.5 Number of unfilled seeds per plant

The mean number of unfilled seeds per head was counted and recorded.

3.8.6 Percent chaffiness

Number of chaffy seeds were counted from total number of seeds and it was expressed in percentage.

3.8.7 Seed yield

The air dried heads from each net plot were threshed, cleaned and the weight of the seeds were recorded. To this, seed yield from five plants that were collected for observations was added to get seed yield per net plot. Based on the grain yield per net plot, grain yield per hectare was calculated.

3.8.8 Stalk yield

Weight of stalks per net plot was recorded after complete sun drying and the yield of stalk per hectare was worked out.

3.8.9 Harvest index

Harvest index is defined as the ratio of economic yield to the biological yield. It was calculated by using the formula given by Donald (1962).

$$H.I. = \frac{\text{Economic yield (q/ha)}}{\text{Biological yield (q/ha)}} = \frac{\text{Grain yield (q/ha)}}{\text{Grain yield (q/ha)} + \text{stalk yield (q/ha)}}$$

3.9 Seed oil content and oil yield per hectare

Oil estimation was done at Regional Research Station, Raichur using N.M.R. (Nuclear Magnetic Resonance) spectrometer by placing the seeds in the test tube provided with instrument, oil yield per hectare was worked out by multiplying oil content and seed yield per hectare and was expressed in kg per hectare.

3.10 CHEMICAL ANALYSIS OF PLANT SAMPLE

3.10.1 Collection and preparation of plant sample

Plant samples taken for dry matter accumulation and its distribution were used for estimating Nitrogen, Phosphorus and Potassium content in whole plant. The different plant parts were powdered separately in a willey grinding mill and stored in plastic container. Then these stored samples were used for further analysis.

3.10.2 Digestion of plant samples

Powdered plant and seed samples were separately treated with HNO_3, for twelve hours for pre-digestion. Then these pre-digested samples were treated with diacid ($HNO3:HClO_4$) mixture (10:4 ratio) and dissolved in 1:6 dilute HCl. The content was made to known volume by using distilled water. A known quantity of aliqout was used for subsequent nutrient analysis. The following estimations were carried out with the diacid digested samples.

3.10.3 Phosphorus

Phosphorus in plant samples was estimated by vanado phosphoric yellow colour method (Jackson, 1967) by using spectrophotometer at 420 nm and expressed the uptake as kg per hectare.

3.10.4 Potassium

Potassium in the plant sample was estimated with the help of flame photometer (Jakson, 1967) and expressed the uptake as kg per hectare.

3.10.5 Nitrogen estimation in Plant

To determine the N in plant, the powdered plant samples were digested with concentrated sulphuric acid and digestion mixture ($CuSo_4$ + K_2SO_4 + selenium powder). After complete digestion, contents were transferred to distillation unit (Microkjeldhal) and the liberated ammonia was trapped in boric acid (Black 1965) and the amount of nitrogen uptake expressed as kg per hectare.

3.11 CHEMICAL ANALYSIS OF SOIL

Soil samples after harvest of the crop from 0-30 cm soil depth was collected from each treatment in all the three replications. The soil samples were chemically analysed for EC, organic carbon, available nitrogen, phosphorus and potassium.

3.11.1 Organic carbon

Organic carbon was estimated by Walkley and Black's wet oxidation method (Jackson, 1967).

3.11.2 Available Nitrogen

Available nitrogen content in the soil was estimated by alkaline potassium permanganate method as described by Subbaiah and Asija (1956) and expressed in kg per hectare.

3.11.3 Available phosphorus

Available phosphorus was estimated by Olsens method (Muhr *et al.,* 1965). Soil samples were shaken with 0.5 m $NaHCO_3$ (pH 8.9) for five minutes, and filtered. By taking a known quantity of aliquot phosphorus content was determined by adopting chlorostannous reduced molybdo phophoric blue colour method and read at 660 nm on spectrophotometer. The results were expressed in kg per hectare of soil.

3.11.4 Available potassium

Available potassium was determined in 1:5 ammonium acetate extract of the soil using flame photometer (Muhr et al., 1965) and expressed the results in kg per hectare of soil.

3.12 ECONOMICS

The prices in rupee of the inputs that were prevailing at the time of their use were considered for working out of cultivation (Appendix-I). Net returns per hectare was calculated by deducting cost of cultivation per hectare from gross income per hectare. Benefit cost ratio was worked out as follows.

$$\text{Benefit cost ratio} = \frac{\text{Net profit (Rs./ha)}}{\text{Cost of cultivation (RS/ha)}}$$

3.13 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used in `F' and 't' tests was P=0.05. Critical difference values were calculated wherever the `F' test was significant. Correlation coefficients have been worked as per Gomez and Gomez (1984).

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the experiment conducted to study the effect of integrated nutrient management on growth, yield and oil content of sunflower grown in red sandy loam soil during *rabi/summer* 1996 are presented in this chapter.

4.1 GROWTH PARAMETERS

4.1.1 Plant height (cm)

The data pertaining to plant height recorded at different stages of crop growth (30, 60 days after sowing and at harvest) as influenced by various treatments are presented in Table 3.

The data revealed that there was significant difference in plant height between the various treatments at all the stages of crop growth. At 30 DAS the treatment which received FYM @ 8 tonnes per hectare + 100 per cent RDF (T_4) recorded maximum plant height of 21.13 cm, which was *on par* with T_{16}, T_1, T_7, T_{13}, T_10, T_8 and T_5. Significantly lower plant height (11.40 cm) was noticed with inoculation of PSM @ 375 g per hectare (T_9) and it was on par with T_{15}, T_3 and T_6 treatments.

At 60 DAS inoculation of PSM @ 375 g per hectare (T_9) recorded significantly lowest plant height (72.76 cm) over rest of the treatments except PSM + Vermicompost @ 2 tonnes per hectare (T_6) treatment. Significantly higher plant height (109.27 cm) was observed with PSM + FYM + 100 per cent RDF (T_{13}) which was *on par* with T_{16}, T_4, T_7, T_{10}, T_1 and T_5 treatments.

At harvest highest plant height of 118.16 cm was recorded in the treatment which received PSM + FYM + 100 per cent (T_{13}) which was statistically *on par* with T_{16}, T_7, T_4, T_{10}, T_5 and T_1 treatments while the lowest plant height (75.67 cm) was noticed in treatment which received only PSM @ 375 g per hectare (T_9)

Table 3 : Effect of integrated nutrient management on plant height (cm) at different growth stages of sunflower

Treatments	Days after sowing		At harvest
	30	60	
1. 100% RDF	21.27	102.93	108.80
2. 75% RDF	16.53	92.73	98.36
3. FYM @ 8 t/ha	12.25	81.33	89.93
4. FYM @ 8 t/ha + 100% RDF	21.13	104.80	109.32
5. FYM @ 8 t/ha + 75% RDF	18.50	98.20	108.81
6. Vermicompost @ 2 t/ha	12.02	75.40	87.14
7. Vermicompost @ 2 t/ha + 100% RDF	20.67	103.27	110.81
8. Vermicompost @ 2 t/ha + 75% RDF	19.18	95.20	100.97
9. PSM @ 375 g/ha	11.40	72.76	75.67
10. PSM @ 375 g/ha + 100% RDF	19.46	103.20	109.11
11. PSM @ 375 g/ha + 75% RDF	17.22	93.09	98.65
12. PSM @ 375 g/ha + FYM @ 8 t/ha	15.05	91.26	95.13
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	20.47	109.27	118.16
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	17.63	92.40	96.83
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	14.23	87.87	87.79
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	21.90	106.33	112.26
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	16.30	93.50	96.84
S.Em ±	1.28	4.69	4.52
CD(0.05)	3.69	13.53	13.03

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

and was *on par* with T_{15} and T_6 treatments. Treatments T_{11}, T_2, T_{12}, T_{14}, and T_3 were *on par* with each other with respect to plant height.

4.1.2 Leaf area

Data regarding leaf area (cm^2/plant) recorded at different crop growth stages (30, 60 DAS and at harvest) are presented in Table 4. Leaf area increased upto 60 DAS and then decreased in all the treatments.

At 30 days, highest leaf area of 551.51 cm^2/plant was recorded in PSM + FYM + 100 per cent RDF (T_{13}) and it was significantly superior over rest of the treatments except T_{16}, and T_7, which recorded 514.06 and 499.63 cm^2/plant respectively. The next best treatments in the order for increased leaf area were T_4 (454.53 cm^2/plant), T_{14} (390.05 cm^2/plant) and T_5 (387.01 cm^2/plant). Lowest leaf area of 203.41 cm^2/plant was observed in PSM @ 375 g per hectare and it was *on par* with T_3, T_{12}, T_{15} and T_6 treatments.

At 60 DAS lower leaf area was observed in the treatment which received PSM @ 375 g per hectare (T_9) (792.86 cm^2/plant) and it was on par with T_3, T_{12}, T_6 and T_{15}. The highest leaf area of 2010.43 cm^2/plant was recorded in PSM + FYM + 100 per cent RDF treatment (T_{13}) which was on par with T_{16}, T_{10}, T_4, T_7, T_5 and T_1 treatments.

At harvest, highest leaf area was observed in PSM + FYM + 100 per cent RDF (T_{13}) treatment (1629.95 cm^2/plant) and it was statistically *on par* with T_{16}, T_{10}, T_4 and T_7 treatments. The lowest leaf area was noticed in treatment which received only PSM @ 375 g per hectare (T_9) (697.62 cm^2/plant) and it was *on par* with T_3, T_6, T_{12} and T_{15} treatments.

Table 4 : Effect of integrated nutrient management on leaf area per plant (cm^2) during different growth stages of sunflower

Treatments	Days after sowing		At harvest
	30	60	
1. 100% RDF	344.86	1555.85	1260.42
2. 75% RDF	285.94	1397.95	1072.92
3. FYM @ 8 t/ha	203.55	899.59	718.67
4. FYM @ 8 t/ha + 100% RDF	454.53	1756.65	1795.05
5. FYM @ 8 t/ha + 75% RDF	387.01	1571.31	1379.33
6. Vermicompost @ 2 t/ha	233.50	1007.41	825.73
7. Vermicompost @ 2 t/ha + 100% RDF	499.63	1751.31	1379.33
8. Vermicompost @ 2 t/ha + 75% RDF	351.81	1484.04	1203.63
9. PSM @ 375 g/ha	203.41	792.86	679.62
10. PSM @ 375 g/ha + 100% RDF	422.21	1765.40	1426.34
11. PSM @ 375 g/ha + 75% RDF	347.34	1455.64	1170.59
12. PSM @ 375 g/ha + FYM @ 8 t/ha	205.67	902.86	931.82
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	511.51	2010.43	1629.95
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	390.05	1428.98	1166.61
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	227.50	1022.35	940.71
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	514.06	1893.99	1538.86
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	353.00	1293.99	1124.77
S.Em ±	25.76	164.75	97.07
CD(0.05)	74.23	474.64	279.67

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

4.1.3 Leaf area index (LAI)

The data pertaining to leaf area index recorded at different crop growth stages are presented in Table 5. Significant difference among the treatments at all the stages of crop growth was observed. Leaf area index increased upto 60 DAS and decreased at harvest.

At 30 DAS, maximum leaf area index of 0.46 was observed in the treatment which received PSM + FYM + 100 per cent RDF (T_{13}) and it was *on par* with PSM + vermicompost + 100 per cent RDF (T_{16}) treatment (0.429). The leaf area index did not differed significantly among the treatments T_4(0.379), T_{10}(0.375), T_7(0.369), T_{14}(0.325) and T_5(0.322). The treatment which received only PSM @ 375 g per hectare (T_9) recorded significantly lowest leaf area index of 0.17 and it was *on par* with T_3, T_{12}, T_{15} and T_6 treatments.

At 60 DAS, significantly lowest leaf area index of 0.66 was recorded in T_9 treatment (PSM @ 375 g/ha) which was on par with T_3, T_{12}, T_6 and T_{15}. Highest leaf area index of 1.67 was noticed in PSM + FYM + 100 RDF (T_{13}) and it was *on par* with T_{16}, T_{10}, T_7,T_4, T_5 and T_1. Rest of the treatments were *on par* with each other.At harvest, maximum leaf area index of 1.36 was recorded in T_{13} treatment which received PSM + FYM + 100 per cent RDF and it was *on par* with T_{16}, T_{10}, T_7 and T_4 treatments, which recorded a leaf area index of 1.28, 1.19, 1.15 and 1.15 respectively. Significantly lowest leaf area of 0.58 was noticed where only PSM @ 375 g per hectare was applied (T_9) and it was *on par* with T_3, T_6, T_{15} treatments.

4.1.4 Leaf area duration (LAD)

Data on leaf area duration (days) recorded at different crop growth stages are presented in Table 5. During both the growth stages (30 to 60 days after sowing and 60 days to harvest), significant differences in leaf area duration were observed among different treatments.

Table 5 : Effect of integrated nutrient management on leaf area index (LAI) and Leaf area duration(LAD) during different growth stages of sunflower

Treatments	Leaf area index			Leaf area duration	
	Days after sowing		At harvest	30 to 60 DAS	60 DAS to harvest
	30	60			
1. 100% RDF	0.287	1.295	1.05	23.73	35.19
2. 75% RDF	0.238	1.265	0.89	21.05	30.89
3. FYM @ 8 t/ha	0.170	0.750	0.60	13.79	20.23
4. FYM @ 8 t/ha + 100% RDF	0.379	1.464	1.75	27.64	39.23
5. FYM @ 8 t/ha + 75% RDF	0.322	1.312	1.06	24.52	34.62
6. Vermicompost @ 2 t/ha	0.194	0.839	0.69	15.51	22.92
7. Vermicompost @ 2 t/ha + 100% RDF	0.369	1.460	1.15	27.42	39.13
8. Vermicompost @ 2 t/ha + 75% RDF	0.293	1.240	1.00	22.95	33.60
9. PSM @ 375 g/ha	0.170	0.660	0.58	12.45	18.63
10. PSM @ 375 g/ha + 100% RDF	0.375	1.470	1.19	27.69	39.90
11. PSM @ 375 g/ha + 75% RDF	0.289	1.210	0.97	22.54	32.83
12. PSM @ 375 g/ha + FYM @ 8 t/ha	0.171	0.750	0.78	13.86	22.94
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	0.460	1.670	1.36	32.02	45.51
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	0.325	1.190	0.97	22.74	32.45
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	0.190	0.850	0.78	15.62	24.54
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	0.429	1.580	1.28	30.10	42.91
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	0.294	1.080	0.94	20.58	30.22
S.Em ±	0.021	0137	0.081	2.15	2.65
CD(0.05)	0.062	0.396	0.233	6.21	7.63

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

During 30 to 60 days period, application of PSM + FYM+100 per cent RDF (T_{13}) recorded significantly higher leaf area duration (32.02 days) and it was *on par* with T_{16}, T_{10}, T_4 and T_7 treatments. Significantly lowest leaf area duration (12.45 days) was noticed in T_9 treatment where only PSM @ 375 g per hectare was applied and it was *on par* with T_3, T_{12}, T_6 and T_{15} treatments.

During 60 days after sowing to harvest, application of PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly highest leaf area duration (45.51 days) and it was *on par* with T_{16}, T_{10}, T_4 and T_7 treatments which recorded a LAD of 42.91, 39.90, 39.23 and 39.13 days respectively. Lowest leaf area duration (18.63 days) was observed in the treatment which received only PSM @ 375 g per hectare (T_9) and it was *on par* with T_3, T_6, T_{12} and T_{15} treatments which recorded LAD of 20.23, 22.92, 22.94, 24.54, days respectively.

4.1.5 Dry matter production per plant and its accumulation in different plant parts

4.1.5.1 At 30 days after sowing

The data on dry matter production per plant and its accumulation in leaves and stem is given in Table 6and Fig. 4. The treatment which received PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly highest total dry matter production (5.56 g/plant) over all other treatments except T_{16} treatment. Significantly lowest total dry matter production was recorded in T_3 (FYM @ 8 t/ha) and it was *on par* with treatments T_{12}, T_{15}, T_6 and T_9 which recorded a dry matter production of 2.33, 2.35, 2.66 and 2.67 g/plant respectively. Application of only FYM (T_3), vermicompost (T_6), PSM (T_9), combination of PSM + FYM (T_{12}) and PSM + vermicompost produced *on par* total dry matter per plant.

The differences in total dry matter production between 75 per cent RDF (T_2) and 100 per cent RDF (T_1) treatments were non significant. While, addition of FYM and PSM to 100 per cent RDF produced significantly higher dry matter production. Further, combination of PSM + FYM+100 per cent RDF (T_{13}) produced significantly higher total dry matter compared to application of PSM + FYM + 100 per cent RDF (T_{10}) and vermicompost + 100 per cent RDF (T_7).

Table 6 : Effect of integrated nutrient management on dry matter production and its accumulation in leaves and stem(g/plant) of sunflower at 30 days after sowing

Treatments	Dry matter production	Dry matter accumulation	
		Leaves	Stem
1. 100% RDF	3.57	2.11	1.46
2. 75% RDF	3.24	2.00	1.23
3. FYM @ 8 t/ha	2.42	1.47	0.96
4. FYM @ 8 t/ha + 100% RDF	4.76	2.53	2.23
5. FYM @ 8 t/ha + 75% RDF	3.59	2.14	1.45
6. Vermicompost @ 2 t/ha	2.66	1.80	0.86
7. Vermicompost @ 2 t/ha + 100% RDF	4.54	2.46	2.33
8. Vermicompost @ 2 t/ha + 75% RDF	4.11	2.39	1.72
9. PSM @ 375 g/ha	2.67	1.69	0.98
10. PSM @ 375 g/ha + 100% RDF	4.12	2.23	1.90
11. PSM @ 375 g/ha + 75% RDF	3.31	2.13	1.17
12. PSM @ 375 g/ha + FYM @ 8 t/ha	2.33	1.36	0.97
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	5.56	3.10	2.46
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	3.89	2.50	1.38
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	2.53	1.41	0.94
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	5.26	3.20	2.33
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	4.00	2.36	1.63
S.Em ±	0.26	0.19	0.17
CD(0.05)	0.74	0.55	0.48

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

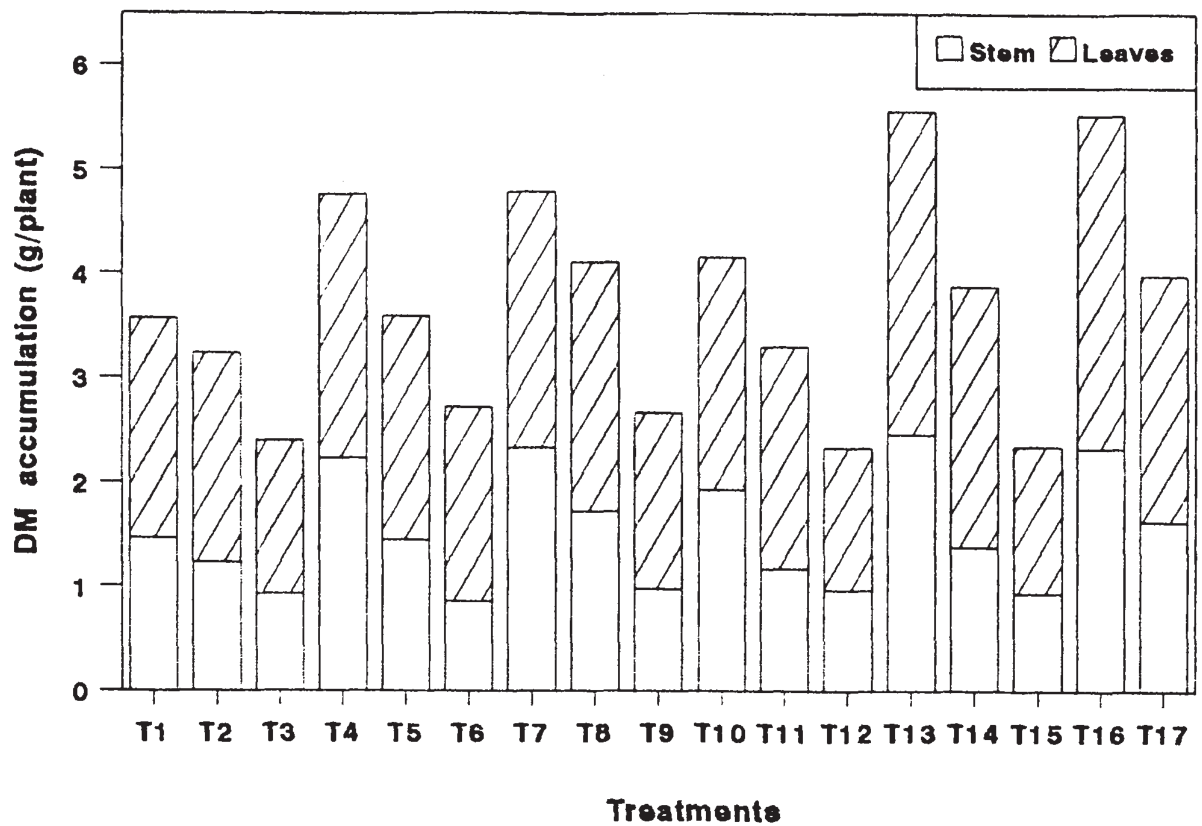

Fig. 4. Effect of integrated nutrient management on dry matter (DM) production and its accumulation in different plant parts at 30 DAS

significantly higher total dry matter compared to application of PSM + FYM + 100 per cent RDF (T_{10}) and vermicompost + 100 per cent RDF (T_7).

Dry matter accumulation in leaves varied significantly due to various treatments. Highest dry matter accumulation in leaves was noticed in treatment which received PSM + vermicompost + 100 per cent RDF (T_{16}) followed by treatment which received PSM + FYM + 100 per cent RDF (T_{13}) and these two treatments were significantly superior to rest of the treatments. Significantly lower dry matter accumulation in leaves was observed in T_{12} treatment than rest of the treatments except T_{15}, T_3, T_9 and T_6 treatments where it was *on par*.

The differences in dry matter accumulation in stem was significant. Dry matter accumulation in T_{13} (2.46 g/plant) was significantly higher over all other treatments except T_{16} (2.33 g/plant), T_7 (2.33g/plant) and T_4 (2.23 g/plant) treatments. Significantly lowest dry matter accumulation in stem was noticed in T_6 (0.86 g/plant) than all other treatments except T_{15}, T_3, T_{12}, T_9 and T_2 treatments which produced 0.94, 0.96, 0.97, 0.98 and 1.23 g/plant respectively.

4.1.5.2 At 60 days after sowing (DAS)

Dry matter production and its accumulation in leaves, stem and head significantly varied and the data is presented in Table 7 and Fig. 5. The treatment which received PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly higher total dry matter production (46.93 g/plant) over all other treatments except T_{16} (PSM + vermicompost 100% RDF). Significantly lower total dry matter production was noticed in T_9 treatment than all other treatments except T_3 and T_6 treatments.

The maximum dry matter accumulation in leaves (13.42 g/plant) was observed in PSM + vermicompost + 100 per cent RDF (T_{16}) treatment. However, it was *on par* with T_{13}, T_{10}, T_4 and T_{14} treatments. The minimum dry matter accumulation in leaves (4.40 g/plant) was observed in PSM @ 375 g per hectare applied treatment. However, this was *on par* with T_3 and T_6 treatments. The dry

Table 7 : Effect of integrated nutrient management on dry matter production and its accumulation in leaves, stem and head (g/plant) of sunflower at 60 days after sowing

Treatments	Dry matter production	Dry matter accumulation		
		Leaves	Stem	Head
1. 100% RDF	40.75	11.81	16.25	12.68
2. 75% RDF	33.59	10.75	12.89	10.15
3. FYM @ 8 t/ha	16.65	4.84	5.71	6.10
4. FYM @ 8 t/ha + 100% RDF	40.43	12.45	15.99	11.99
5. FYM @ 8 t/ha + 75% RDF	32.19	10.98	10.60	10.61
6. Vermicompost @ 2 t/ha	18.32	5.31	7.23	5.78
7. Vermicompost @ 2 t/ha + 100% RDF	40.84	11.52	17.06	12.31
8. Vermicompost @ 2 t/ha + 75% RDF	35.92	11.16	13.30	11.46
9. PSM @ 375 g/ha	16.08	4.40	5.90	5.78
10. PSM @ 375 g/ha + 100% RDF	43.01	12.75	16.98	13.28
11. PSM @ 375 g/ha + 75% RDF	36.01	10.82	14.97	10.22
12. PSM @ 375 g/ha + FYM @ 8 t/ha	21.25	6.75	7.24	7.26
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	46.93	13.27	18.99	14.67
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	32.48	11.98	10.00	10.50
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	22.02	7.06	7.81	27.21
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	46.73	13.42	18.40	14.91
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	34.16	11.28	10.81	12.07
S.Em ±	1.19	0.54	0.57	0.85
CD(0.05)	3.45	1.56	1.66	2.45

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

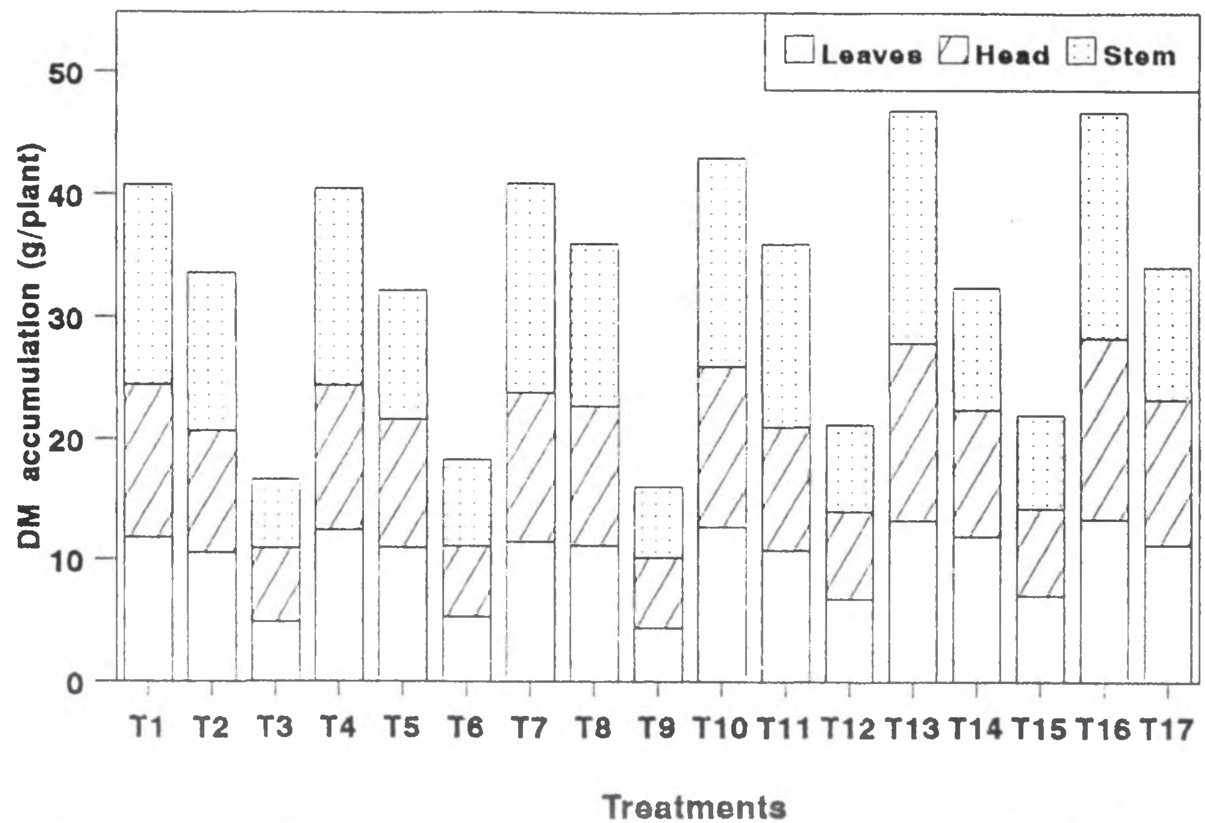

Fig. 5. Effect of integrated nutrient management on dry matter (DM) production and its accmulation in different plant parts at 60 DAS

matter accumulation in leaves in T_1, T_{17}, T_8, T_5, T_{11} and T_2 treatments did not differ significantly.

Treatment which received PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly higher dry matter accumulation in stem (18.99 g/plant) over all other treatments except PSM + vermicompost + 100 per cent RDF (T_{16}). Significantly lower dry matter accumulation in stem was noticed in treatment T_3 (5.71 g/plant). However, it was on par with T_9 and T_6 treatments. The treatment which received PSM + 75 per cent RDF recorded 14.97 g/plant of dry matter in stem which was *on par* with the treatment receiving vermicompost + 75 per cent RDF. These two treatments were significantly superior when compared to T_{17}, T_5 and T_{14} treatments.

Dry matter accumulation in head was significantly higher in T_{16} treatment which received PSM + vermicompost + 100 per cent RDF than all other treatments except T_{13}, T_{10} and T_1 treatments. The next best treatments in order with respect to dry matter accumulation in head were T_7, T_{17}, T_4, T_8, T_5, T_{14}, T_{11} and T_2. The lowest dry matter accumulation in head was noticed in T_9 (5.78 g/plant). However, this treatment was on par with T_6, T_3, T_{15} and T_{12} treatments.

4.1.5.3 At harvest

Data pertaining to dry matter production and its accumulation in different plant parts are presented in Table 8 and Fig. 6. The treatments differed significantly with regard to total dry matter production and its accumulation in different parts at harvest.

The highest dry matter production was observed in treatment which received PSM + vermicompost + 100 per cent RDF (72.46 g/plant) and it was *on par* with the treatments receiving PSM + FYM + 100 per cent RDF (T_{13}), PSM + 100 per cent RDF (T_{10}), vermicompost + 100 per cent RDF (T_7) and FYM + 100 per cent RDF (T_4). The lowest dry matter production of 32.73 g/plant was observed in

Table 8: Effect of integrated nutrient management on dry matter production and its accumulation in leaves, stem and head (g/plant) of sunflower at harvest

Treatments	Dry matter production	Dry matter accumulation		
		Leaves	Stem	Head
1. 100% RDF	60.94	12.53	15.20	33.11
2. 75% RDF	52.45	11.92	12.07	28.26
3. FYM @ 8 t/ha	32.73	3.37	3.43	25.93
4. FYM @ 8 t/ha + 100% RDF	62.07	14.21	15.71	32.15
5. FYM @ 8 t/ha + 75% RDF	56.61	12.70	13.67	30.24
6. Vermicompost @ 2 t/ha	42.85	8.57	7.67	26.61
7. Vermicompost @ 2 t/ha + 100% RDF	62.70	11.80	14.89	36.01
8. Vermicompost @ 2 t/ha + 75% RDF	54.18	11.07	12.17	30.94
9. PSM @ 375 g/ha	38.39	5.27	6.24	26.88
10. PSM @ 375 g/ha + 100% RDF	61.63	10.51	12.10	39.02
11. PSM @ 375 g/ha + 75% RDF	53.05	10.16	11.26	31.63
12. PSM @ 375 g/ha + FYM @ 8 t/ha	40.65	7.94	7.20	25.51
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	68.24	13.04	16.08	39.12
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	55.73	11.06	13.11	31.56
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	43.14	5.92	8.06	29.16
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	72.46	14.10	20.13	38.23
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	53.29	10.72	13.20	29.37
S.Em ±	2.32	0.79	1.36	2.08
CD(0.05)	6.67	2.28	3.91	6.00

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

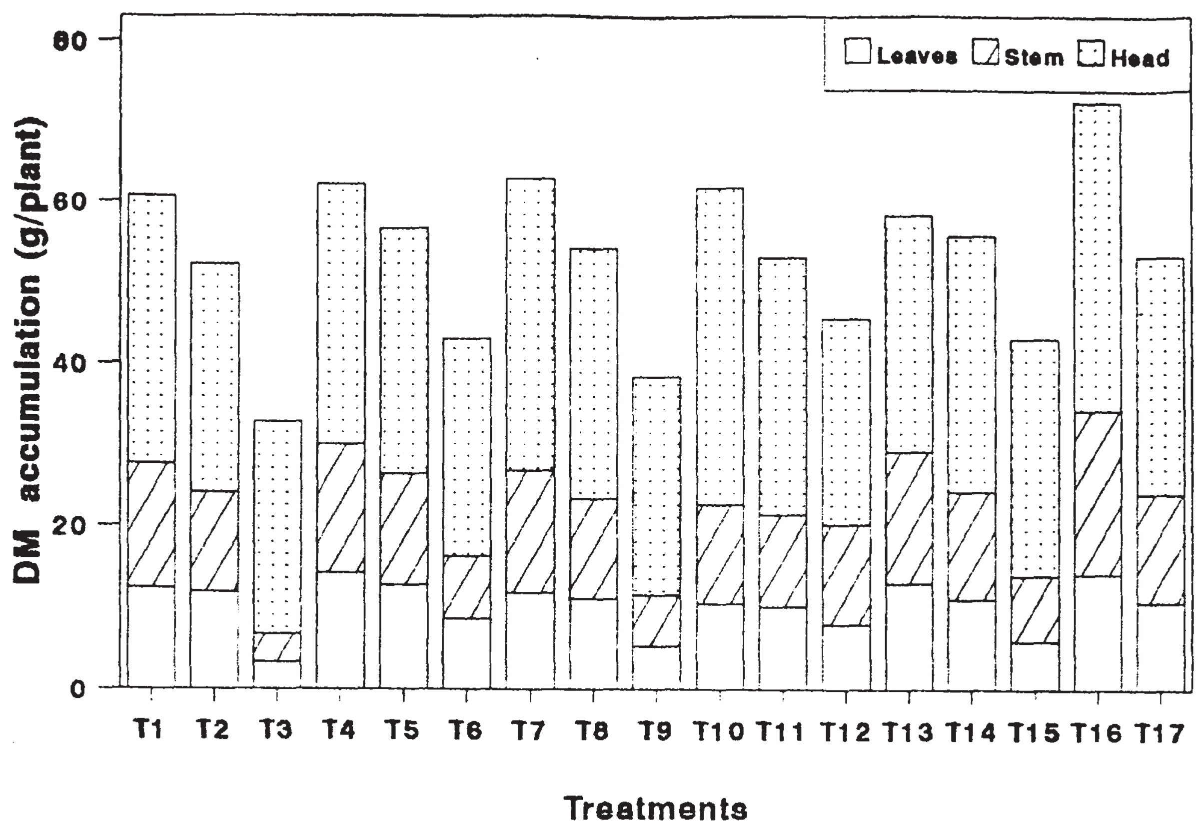

Fig. 6. Effect of integrated nutrient management on dry matter(DM) production and its accumulation in differnt plant parts at harvest

FYM @ 8 tonnes per hectare (T_3) as compared to all other treatments except PSM @ 375 g per hectare (T_9).

Treatment receiving FYM + 100 per cent RDF (T_4) recorded significantly higher dry matter accumulation in leaves (14.21 g/plant), when compared to all other treatments except T_{16}, T_5 and T_1 which were *on par* with each other. Application of only FYM @ 8 tonnes per hectare (T_3) produced significantly lower dry matter accumulation in leaves (3.37 g/plant) as compared to all other treatments and it was *on par* with the treatment receiving only PSM (T_9).

Highest dry matter accumulation in stem (20.13 g/plant) was observed in PSM + vermicompost + 100 per cent RDF (T_{16}) treatment compared to all other treatments. Significantly lower dry matter accumulation in stem was observed in FYM @ 8 tonnes per hectare (T_4) treatment. However, it was *on par* with PSM @ 375 g per hectare (T_9) applied treatment. Dry matter accumulation in stem in T_{12}, T_6 and T_{15} did not differed significantly. Similarly the dry matter accumulation in stem did not differ significantly between the treatments T_1, T_4, T_5, T_7, T_8, T_{13}, T_{14} and T_{17}. Significantly higher dry matter accumulation in head was recorded in PSM + FYM + 100 per cent RDF (T_{13}) treatment (39.12 g/plant) than all other treatments. However, it was *on par* with T_{10} (PSM + 100% RDF), T_{16} (PSM + vermicompost + 100% RDF) and T_7 (Vermicompost + 100% RDF) treatments. The treatment which received PSM + FYM (T_{12}) recorded significantly lower dry matter in head (25.51 g/plant) when compared to T_1, T_4, T_{11} and T_{14} treatments. However, it was *on par* with T_8, T_5, T_{17}, T_{15}, T_2, T_9, T_6 and T_3 treatments.

4.1.6 Rate of dry matter accumulation (RDMA)

Data on rate of dry matter accumulation (g/g/day) recorded at different crop growth stages are presented in Table 9. During both the growth stages (30 to 60 DAS and 60 DAS to harvest), significant difference in RDMA was observed among different treatments.

Table 9: Effect of integrated nutrient management on rate of dry matter accumulation (RDMA) and relative growth rate(RGR) at different growth stages of sunflower

Treatments	RDMA (g/g/day)		RGR (g/g/day)	
	30 to 60 DAS	60 DAS to harvest	30 to 60 DAS	60 DAS to harvest
1. 100% RDF	1.239	0.673	0.081	0.013
2. 75% RDF	1.012	0.629	0.078	0.015
3. FYM @ 8 t/ha	0.473	0.536	0.064	0.022
4. FYM @ 8 t/ha + 100% RDF	1.189	0.721	0.071	0.014
5. FYM @ 8 t/ha + 75% RDF	0.953	0.814	0.074	0.019
6. Vermicompost @ 2 t/ha	0.522	0.818	0.064	0.028
7. Vermicompost @ 2 t/ha + 100% RDF	1.212	0.727	0.073	0.014
8. Vermicompost @ 2 t/ha + 75% RDF	1.060	0.609	0.072	0.017
9. PSM @ 375 g/ha	0.447	0.744	0.067	0.029
10. PSM @ 375 g/ha + 100% RDF	1.295	0.621	0.078	0.012
11. PSM @ 375 g/ha + 75% RDF	0.757	0.568	0.079	0.013
12. PSM @ 375 g/ha + FYM @ 8 t/ha	0.631	0.547	0.074	0.022
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	1.379	0.713	0.071	0.012
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	0.953	0.775	0.071	0.018
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	0.658	0.702	0.077	0.022
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	1.382	0.553	0.073	0.010
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	1.005	0.638	0.071	0.015
S.Em ±	0.097	0.008	0.004	0.001
CD(0.05)	0.280	0.022	NS	0.004

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

During 30 to 60 days period, application of PSM + vermicompost + 100 per cent RDF (T_{16}) recorded significantly higher rate of dry matter accumulation (1.382 g/g/day) and it was *on par* with T_{13}, T_{10}, T_1, T_7 and T_4 treatments. Significantly lowest RDM (0.473 g/g/day) was noticed in T_3 treatment where only FYM @ 8 tonnes per hectare was applied and it was *on par* with T_9, T_6, T_{12} and T_{15} treatments.

During 60 days after sowing to harvest, application of vermicompost @ 2 tonnes per hectare (T_6) recorded significantly higher RDMA (0.818 g/g/day) and it was *on par* with T_5 treatment, which recorded 0.814 g/g/day. Application of only FYM @ 8 tonnes per hectare recorded significantly lower rate of dry matter accumulation (0.536 g/g/day) and it was *on par* with T_{12}, T_{16} and T_{11} treatments which recorded RDMA of 0.547, 0.553 and 0.568 g/g/day respectively.

4.1.7 Relative growth rate (RGR)

Data on relative growth rate (g/g/day) recorded at different crop growth stages are presented in Table 9. The influence of organic source of nutrient, inorganic source of nutrient and combined application of these nutrients on RGR of sunflower was not significant during the period from 30 to 60 DAS, however during 60 DAS to harvest, significant differences in RGR was noticed.

During 60 DAS to harvest, application of PSM @ 375 g per hectare (T_9) recorded significantly higher RGR (0.029 g/g/day) and it was on par with T_6 treatment, which recorded 0.028 g/g/day. Significantly lowest RGR (0.010 g/g/day) was noticed in T_{16} treatment and it was *on par* with T_{13}, T_{10}, T_1, T_{12} and T_4 treatments.

4.1.8 Crop growth rate (CGR)

The data regarding crop growth rate (g/dm^2/day) are presented in Table 10. The influence of different treatments on CGR of sunflower was significant during both the stages of crop growth. During the period from 30 to 60 DAS,

Table 10: Effect of integrated nutrient management on crop growth rate (CGR) and net assimilation rate (NAR) at different growth stages of sunflower

Treatments	CGR ($g/dm^2/day$)		NAR(($g/dm^2/day$)	
	30 to 60 DAS	60 DAS to harvest	30 to 60 DAS	60 DAS to harvest
1. 100% RDF	0.103	0.056	0.154	0.050
2. 75% RDF	0.088	0.052	0.137	0.051
3. FYM @ 8 t/ha	0.039	0.045	0.101	0.109
4. FYM @ 8 t/ha + 100% RDF	0.099	0.060	0.123	0.040
5. FYM @ 8 t/ha + 75% RDF	0.079	0.068	0.114	0.060
6. Vermicompost @ 2 t/ha	0.043	0.068	0.099	0.089
7. Vermicompost @ 2 t/ha + 100% RDF	0.101	0.060	0.121	0.044
8. Vermicompost @ 2 t/ha + 75% RDF	0.091	0.051	0.136	0.045
9. PSM @ 375 g/ha	0.041	0.062	0.103	0.100
10. PSM @ 375 g/ha + 100% RDF	0.105	0.052	0.136	0.039
11. PSM @ 375 g/ha + 75% RDF	0.091	0.047	0.141	0.043
12. PSM @ 375 g/ha + FYM @ 8 t/ha	0.052	0.054	0.134	0.072
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	0.115	0.059	0.122	0.039
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	0.079	0.064	0.119	0.080
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	0.055	0.058	0.124	0.071
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	0.115	0.046	0.131	0.032
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	0.082	0.053	0.139	0.053
S.Em ±	0.003	0.003	0.009	0.004
CD(0.05)	0..008	0.007	0.027	0.011

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

application of PSM + FYM (T_{13}) and vermicompost + 100 per cent RDF (T_{16}) recorded significantly higher CGR (0.115 $g/dm^2/day$) than all other treatments. Significantly lower CGR (0.039 $g/dm^2/day$) was noticed in T_3 treatment which received only FYM @ 8 tonnes per hectare and it was *on par* with T_9 and T_6 treatments.

During the period from 60 days after sowing to harvest, application of FYM + 75 per cent RDF(T_5) and only vermicompost @ 2 tonnes per hectare (T_6) recorded significantly higher CGR (0.068 $g/dm^2/day$) and it was *on par* with T_{14} and T_9 treatments. Application of only FYM @ 8 tonnes per hectare (T_4) recorded significantly lower CGR (0.045 $g/dm^2/day$) than other treatments except T_{16}(0.046 $g/dm^2/day$), T_{11} (0.047 $g/dm^2/day$), T_8(0.051 $g/dm^2/day$), T_2 (0.052 $g/dm^2/day$) and T_{10}(0.052 $g/dm^2/day$) treatments which were *on par* with each other.

4.1.9 Net assimilation rate (NAR)

The data on net assimilation rate ($g/dm^2/day$) as influenced by different treatments are presented in Table 10. During both growth stages (30 to 60 DAS and 60 DAS to harvest), significant difference in NAR was observed among different treatments. During the period from 30 to 60 DAS, application of only 100 per cent RDF (T_1) recorded significantly higher NAR (0.154 $g/dm^2/day$) and it was *on par* with T_{11}, T_{17}, T_2, T_{12}, T_8, T_{10} and T_{16} treatments. Significantly lowest NAR (0.099 $g/dm^2/day$) was noticed in treatment T_6, which received only vermicompost @ 2 tonnes per hectare and it was *on par* with T_3, T_5, T_{14}, T_7, T_{13}, T_4 and T_{15} treatments which recorded NAR of 0.101, 0.114, 0.119, 0.121, 0.122, 0.123 and 0.124 $g/dm^2/day$ respectively.

During 60 DAS to harvest, application FYM @ 8 tonnes per hectare recorded significantly higher (0.109 $g/dm^2/day$) NAR than all other treatments except T_9 treatment which recorded 0.100 $g/dm^2/day$. Lowest net assimilation rate was noticed in T_{16} (0.032 $g/dm^2/day$) as compared to all other treatments except T_{10}, T_{13}, T_4 and T_{11} treatments which recorded a NAR of 0.039, 0.039, 0.040 and 0.043 $g/dm^2/day$ respectively.

4.2 YIELD COMPONENTS AND YIELD

The effect of integrated nutrient management on head diameter, number of filled, unfilled and total seeds per head, 1000 seed weight, seed and stalk yield, harvest index, oil content and oil yield of sunflower were studied.

4.2.1 Head diameter

The data on head diameter (cm) at 60 DAS and harvest as influenced by various treatments are presented in Table 11. The variation in head diameter at 60 DAS and harvest due to different treatments was significant. At 60 DAS, application of PSM + FYM +100 per cent RDF(T_{13}) recorded significantly higher head diameter (12.49 cm) than T_2, T_3, T_6, T_8, T_9, T_{12}, T_{15} and T_{17} and was *on par* with T_{16}, T_7, T_4, T_{14}, T_1, T_{10}, T_5 and T_{11} treatments.

Significantly lower head diameter of 7.43 cm was observed due to application of FYM @ 8 tonnes per hectare (T_3). However, it was *on par* with T_8, T_9, T_{12}, T_6, T_2, T_{17} and T_{15} treatments. At harvest, significantly higher head diameter (14.25 cm) was recorded in PSM + vermicompost + 100 per cent RDF (T_{16}) treatment than all other treatments except PSM + FYM + 100 per cent RDF treatment (T_{13}) which recorded a head diameter of 13.46 cm. The next best treatments in order were T_{10}(12.99 cm), T_4(12.97 cm), T_{14}(12.91 cm) and T_7 (12.28 cm). Significantly lower head diameter of 9.53 cm was noticed in treatment, where only PSM @ 357 g per hectare (T_9) than all other treatments except T_5, T_3, T_{12}, T_6 and T_{15} treatments, which recorded a head diameter of 10.73, 10.51, 10.37, 9.8 and 9.73 cm respectively.

4.2.2 Number of unfilled seeds per head.

The data on number of unfilled seeds per head are presented in Table 12. Significantly lower unfilled seeds per head (23.60) was recorded in treatment which received PSM + FYM + 100 per cent RDF (T_{13}) than all other treatments except T_{16},

Table 11: Effect of integrated nutrient management on head diameter (cm) of sunflower

Treatments	Head diameter	
	60 DAS	Harvest
1. 100% RDF	10.77	11.36
2. 75% RDF	8.83	10.53
3. FYM @ 8 t/ha	7.43	10.51
4. FYM @ 8 t/ha + 100% RDF	11.20	12.97
5. FYM @ 8 t/ha + 75% RDF	10.26	10.73
6. Vermicompost @ 2 t/ha	8.94	9.80
7. Vermicompost @ 2 t/ha + 100% RDF	11.23	12.28
8. Vermicompost @ 2 t/ha + 75% RDF	9.43	11.43
9. PSM @ 375 g/ha	9.20	9.53
10. PSM @ 375 g/ha + 100% RDF	10.63	12.99
11. PSM @ 375 g/ha + 75% RDF	10.03	11.07
12. PSM @ 375 g/ha + FYM @ 8 t/ha	9.17	10.37
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	12.49	13.46
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	10.83	12.91
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	7.96	9.73
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	12.16	14.25
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	8.57	10.30
S.Em ±	0.894	0.43
CD(0.05)	2.70	1.25

RDF = Recommended dose of fertilizer (60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

T_5, and T_4 treatments. The number of unfilled seeds per head were significantly higher (80.31) in treatments which received only vermicompost applied @ 2 tonnes per hectare than all other treatments except T_9 (78.82) which received only PSM @ 375 g/ha.

4.2.3 Number of filled seeds per head

The data pertaining to number of filled seeds per head as influenced by various treatments are presented in Table 12. Maximum number of filled seeds per head (432.6) was recorded in PSM + FYM + 100 per cent RDF (T_{13}) as compared to all other treatments except PSM + vermicompost + 100 per cent RDF (T_{16}). Minimum number of filled seeds per head (183.23) were observed in PSM @ 375 g per hectare (T_9) treatment and it was *on par* with the treatments receiving only vermicompost @ 2 tonnes per hectare (T_6) and only FYM @ 8 tonnes per hectare (T_3).

4.2.4 Total number of seeds per head

The data pertaining to total number of seeds per head as influenced by different treatments are presented in Table 12. The treatments differed significantly with regard to total number of seeds per head. Maximum total number of seeds per head (456.20) were recorded in treatment receiving PSM+ FYM+ 100 per cent RDF (T_{13}) and followed by T_{16}, T_7, T_{10}, T_{11}, T_1, and T_4 treatments which recorded 429.23, 416.07, 416.03, 402.87, 400.80 and 399.86 total number of seeds per head and were on par with each other. The T_5, T_8, T_{17} and T_{14} treatments did not differ significantly with respect to total number of seeds per head.

Significantly lowest number of seeds per head (262.05) were observed in treatment which received only PSM @ 375 gm/ha than all other treatments except T_3, T_6, T_2, T_{15} and T_{12} treatments which recorded 272.36, 279.93, 297.43, 305.07 and 312.33 total number of seeds per head respectively.

Table 12: Effect of integrated nutrient management on number of filled seeds, unfilled seeds, total number of seeds per head and 1000 seed weight(g) of sunflower

Treatments	Number of seeds per head			Chaffiness (%)	1000 seed weight(g)
	Unfilled	Filled	Total		
1. 100% RDF	32.07	368.73	400.80	8.00	48.07
2. 75% RDF	46.33	251.10	297.43	15.57	45.16
3. FYM @ 8 t/ha	61.36	211.03	277.36	22.52	41.30
4. FYM @ 8 t/ha + 100% RDF	27.53	372.33	399.86	6.88	50.67
5. FYM @ 8 t/ha + 75% RDF	24.54	360.60	385.13	6.38	47.13
6. Vermicompost @ 2 t/ha	80.31	199.60	279.93	28.70	43.63
7. Vermicompost @ 2 t/ha + 100% RDF	34.27	381.80	416.07	8.24	52.77
8. Vermicompost @ 2 t/ha + 75% RDF	47.00	318.47	365.47	12.86	49.34
9. PSM @ 375 g/ha	78.82	183.23	262.05	30.08	44.79
10. PSM @ 375 g/ha + 100% RDF	37.60	378.43	416.03	9.04	50.83
11. PSM @ 375 g/ha + 75% RDF	58.37	344.33	402.87	14.49	46.93
12. PSM @ 375 g/ha + FYM @ 8 t/ha	62.18	250.20	312.33	19.89	43.82
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	23.60	432.60	456.20	5.17	54.81
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	44.80	280.50	325.30	13.77	47.74
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	58.20	246.87	305.07	18.97	42.86
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	26.73	402.90	429.63	6.22	53.89
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	62.14	298.67	360.80	17.22	46.27
S.Em ±	1.37	11.79	21.01	0.64	1.23
CD(0.05)	3.94	33.95	60.54	1.85	3.54

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

4.2.5 *Per cent chaffiness*

Per cent chaffiness as influenced by different treatments are presented in Table 12. Treatment receiving PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly lowest per cent chaffiness (5.17) than all other treatments except T_{16}, T_5 and T_4 which recorded 6.22, 6.38 and 6.88 per cent chaffiness respectively. Significantly highest per cent chaffiness (30.08) was recorded in treatment which received only PSM @ 375 g per hectare (T_9).

4.2.6 *Thousand seed weight*

The data regarding thousand seed weight (g) in sunflower as influenced by various treatments are presented in Table 12. The variation in thousand seed weight of sunflower due to different treatments was significant. Significantly higher thousand seed weight (54.819) was obtained in treatment which received PSM + FYM + 100 per cent RDF (T_{13}) over all other treatments except T_{16} and T_7 treatments which recorded a thousand seed weight of 53.89 g and 53.77 g respectively. There was no significant difference in thousand seed weight between T_5, T_{11}, T_{17}, T_2, T_{12}, and T_6 which recorded a thousand seed weight of 47.13 g, 46.93 g, 46.27 g, 45.16 g, 43.82 g and 43.63 g respectively.

The treatment which received only FYM @ 8 tonnes per hectare (T_3) recorded significantly lowest thousand seed weight (41.30 g) compared to all other treatments except T_6, T_9, T_{12} and T_{15} treatments, which recorded lowest thousand seed weight of 43.63 g, 44.79 g, 43.82 g, and 42.86 g respectively.

4.2.7 *Seed yield of sunflower*

The data on seed yield of sunflower as influenced by different treatments are presented in Table 13 and Fig. 7. The seed yield of sunflower differed significantly due to different treatments. Application of PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly higher seed yield of 1143 kg per hectare as compared to all other treatments except T_{16} which recorded a seed yield of 1084 kg per hectare.

Application of only PSM @ 375 g per hectare (T_9) recorded significantly lowest seed yield (379 kg/ha) as compared to all other treatments except T_3 treatment which recorded a seed yield of 464 kg per hectare .

Application of PSM + vermicompost + 50 per cent RDF (T_{17}) and PSM + FYM + 50 per cent RDF (T_{14}) produced *on par* seed yield and these in turn were *on par* with application of 100 per cent RDF (T_1) alone. While, application of PSM +vermicompost +100 per cent RDF (T_{16}) and PSM + FYM + 100 per cent RDF (T_{13}) produced *on par* seed yield and in turn were significantly superior to application of 100 per cent RDF (T_1) alone.

4.2.8 Stalk yield of sunflower

The data on stalk yield as influenced by various treatments are presented in Table 13 and Fig. 7. Stalk yield differed significantly due to different treatments. Application of FYM + 100 per cent RDF (T_4) recorded significantly higher stalk yield (1918 kg/ha) than all other treatments except T_{13}, T_7, T_{16}, T_{10}, T_{17}, T_1, T_8 and T_{11} treatments.

The treatment which received only PSM @ 375 g per hectare (T_9) recorded significantly lowest stalk yield of 987 kg per hectare compared to all other treatments except T_3 treatment which recorded a stalk yield of 990 kg per hectare.

4.2.9 Harvest index of sunflower.

The data on harvest index as influenced by different treatments are presented in Table 13. Harvest index differed significantly due to different treatments. Significantly highest harvest index of 0.38 was recorded in treatment which received PSM + FYM + 100 per cent RDF (T_{13}) than all other treatments except T_{16}, T_1, T_{10}, T_5, T_8, T_{12}, T_{14}, T_{11},T_7, T_6, T_4 and T_2 treatments. Significantly lowest harvest index of 0.28 was observed in treatment which received only PSM @ 375 g per hectare(T_9) than all other treatments except T_{17}, T_3 and T_{15}.

Table 13: Effect of integrated nutrient management on seed yield, Stalk yield, Harvest index, oil content and oil yield of sunflower

Treatments	Seed yield (kg/ha)	Stalk yield (kg/ha)	Harvest index	Oil content (%)	Oil yield (kg/ha)
1. 100% RDF	933	1766	0.35	40.5	378
2. 75% RDF	819	1496	0.34	40.0	327
3. FYM @ 8 t/ha	464	990	0.32	37.8	175
4. FYM @ 8 t/ha + 100% RDF	979	1918	0.34	41.3	404
5. FYM @ 8 t/ha + 75% RDF	897	1626	0.35	40.5	363
6. Vermicompost @ 2 t/ha	567	1093	0.34	38.0	215
7. Vermicompost @ 2 t/ha + 100% RDF	984	1891	0.34	41.5	208
8. Vermicompost @ 2 t/ha + 75% RDF	937	1765	0.35	40.4	379
9. PSM @ 375 g/ha	379	987	0.28	37.0	140
10. PSM @ 375 g/ha + 100% RDF	969	1823	0.35	41.7	404
11. PSM @ 375 g/ha + 75% RDF	915	1757	0.34	40.5	371
12. PSM @ 375 g/ha + FYM @ 8 t/ha	642	1201	0.35	39.6	254
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	1143	1865.	0.38	41.9	479
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	887	1714	0.34	40.0	385
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	588	1300	0.31	39.2	231
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	1084	1840	0.37	41.7	452
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	852	1766	0.32	40.8	348
S.Em ±	40.58	58.10	0.01	1.20	13.01
CD(0.05)	117	167	0.04	NS	37.48

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

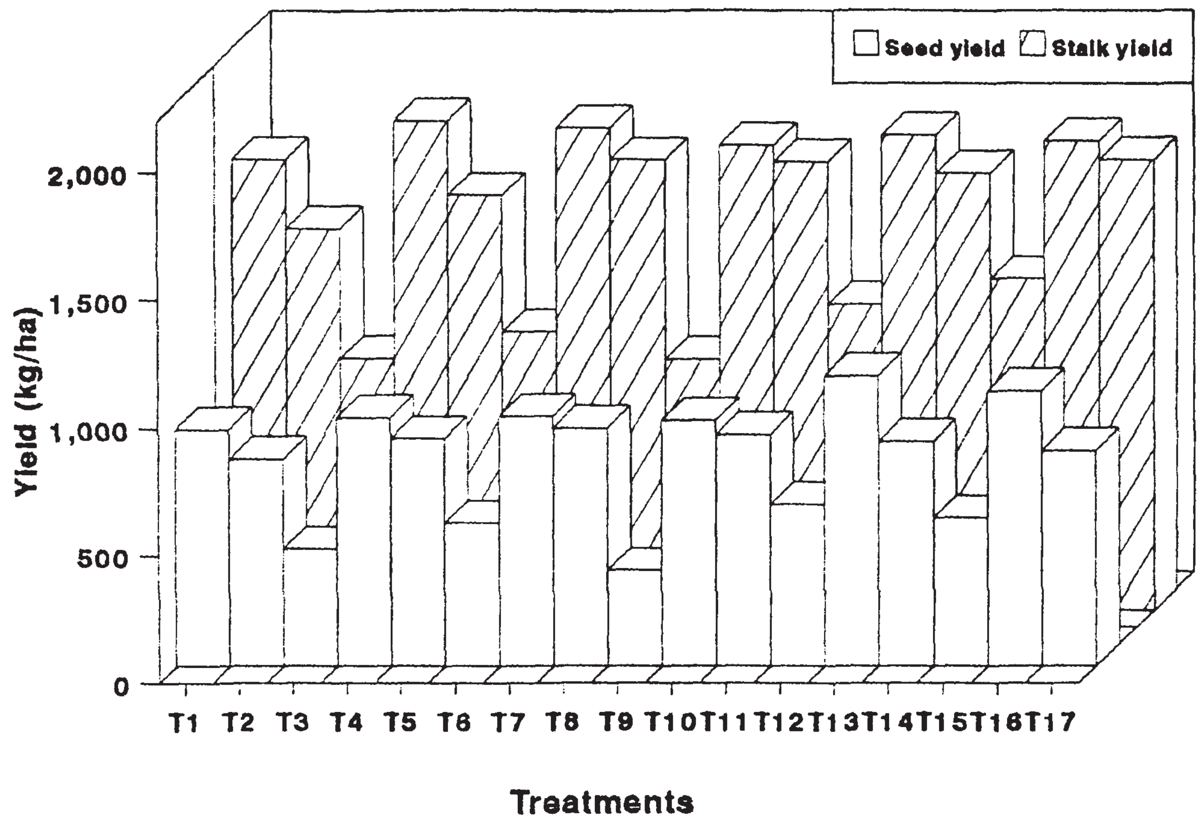

Fig. 7. Effect of integrated nutrient management on seed and stalk yield (kg/ha) of sunflower

4.3 OIL CONTENT AND OIL YIELD OF SUNFLOWER

The data pertaining to oil content and oil yield as influenced by various treatments are presented in Table 13. The data revealed that there was no significant difference in oil content (%) due to various treatments. However, highest oil content of 41.9 per cent was noticed in T_{13} which received PSM + FYM + 100 per cent RDF. Significantly higher oil yield of 479 kg per hectare was noticed, where PSM + FYM + 100 per cent RDF (T_{13}) which was *on par* with (T_{16}), which received PSM + Vermicompost + 100 per cent RDF (452 kg/ha). Application of only PSM @ 375 g per hectare (T_9) recorded significantly lowest oil yield (140 kg/ha) ac compared to all other treatments except T_3 which recorded oil yield of 175 kg per hectare. Application of PSM + FYM + 50 per cent RDF (T_{15}) and PSM + Vermicompost + 50 per cent RDF (T_{17}) produced *on par* oil yield and these inturn were *on par* with application of 100 per cent RDF alone (T_1).

4.4 NUTRIENT UPTAKE BY SUNFLOWER

Sunflower plants were chemically analysed for their nitrogen, phosphorus and potassium at harvest and uptake was calculated.

4.4.1 Nitrogen uptake

The data on uptake as influenced by different treatments are presented in Table 14 and Fig. 8. Uptake of nitrogen by sunflower differed significantly due to various treatments. The plants receiving PSM + Vermicompost + 100 per cent RDF (T_{16}) recorded maximum uptake of nitrogen (125.59 kg/ha) and was significantly superior to all other treatments except T_{13}, T_4, T_{10}, T_7 and T_1 in which the nitrogen uptake was 123.43, 118.91, 115.60, 113.23 and 107.45 kg per hectare respectively.

The differences in the nitrogen uptake among the treatments T_8, T_5, T_{11}, T_2, T_{14} and T_{17} did not differ significantly. The uptake of nitrogen was significantly lowest in treatment receiving only FYM @ 8 tonnes per hectare (T_3) when compared to all other treatments except treatments receiving only vermicompost @ 2 tonnes per hectare (T_6), only PSM @ 375 g per hectare (T_9), PSM + FYM (T_{12}) and PSM + vermicompost (T_{15}).

4.4.2 Phosphorus uptake

Phosphorus uptake by sunflower differed significantly due to different treatments and the data is presented in Table 14 and Fig. 8. Application of PSM + vermicompost + 100 per cent RDF (T_{16}) recorded significantly highest uptake of phosphorus (49.56 kg/ha) as compared to all other treatments except T_{13} and T_{10} in which the P uptake was 46.48 and 42.86 kg per hectare respectively. The phosphorus uptake was significantly lowest (11.59 kg/ha) in T_6 as compared to all other treatments except T_3, T_9, T_{12} and T_{15}, in these treatments the phosphorus uptake was 11.68, 15.25, 18.59, and 19.81 kg per hectare respectively.

4.4.3 Potassium uptake

Potassium uptake by sunflower differed significantly due to different treatments and the data is presented in Table 14 and Fig. 8. Significantly higher (110.48 kg/ha) uptake of potassium was noticed in T1$_3$ (PSM + FYM + 100% RDF) than all other treatments except T_{16}, T_{10}, T_7, T_4 and T_1. The potassium uptake in these treatments was 109.16, 106.98, 105.51, 103.56 and 99.47 kg per hectare respectively. Uptake of potassium did not differ significantly among the treatments T_{14}, T_{17}, T_{11} and T_8.

Significantly lowest potassium uptake was noticed in treatment which received only FYM @ 8 tonnes per hectare (62.89 kg/ha) than all other treatments except T_9, T_6, T_{12}, T_2, T_{15} and T_5.. The uptake of potassium in these treatments was 64.60, 65.65, 69.89, 70.65 and 71.63 kg per hectare respectively.

4.5 SOIL ANALYSIS

Soil samples were analyzed for electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium after harvest of sunflower.

Table 14:Effect of integrated nutrient management on uptake of nutrients by sunflower at harvest

Treatments	Uptake of nutrients (kg/ha)		
	Nitrogen	Phosphorus	Potassium
1. 100% RDF	107.45	32.56	99.47
2. 75% RDF	85.96	22.35	70.65
3. FYM @ 8 t/ha	50.68	11.68	62.89
4. FYM @ 8 t/ha + 100% RDF	118.91	35.84	103.56
5. FYM @ 8 t/ha + 75% RDF	92.58	25.58	75.85
6. Vermicompost @ 2 t/ha	52.62	11.59	65.56
7. Vermicompost @ 2 t/ha + 100% RDF	113.23	38.09	105.51
8. Vermicompost @ 2 t/ha + 75% RDF	93.59	32.56	83.13
9. PSM @ 375 g/ha	53.89	15.25	64.60
10. PSM @ 375 g/ha + 100% RDF	115.60	42.86	106.98
11. PSM @ 375 g/ha + 75% RDF	90.53	35.92	89.05
12. PSM @ 375 g/ha + FYM @ 8 t/ha	58.65	18.59	69.89
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	123.43	46.48	110.48
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	81.59	21.89	92.62
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	60.28	19.81	71.63
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	125.59	49.56	109.16
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	79.56	23.29	90.92
S.Em ±	5.86	3.48	4.93
CD(0.05)	16.89	10.04	14.20

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

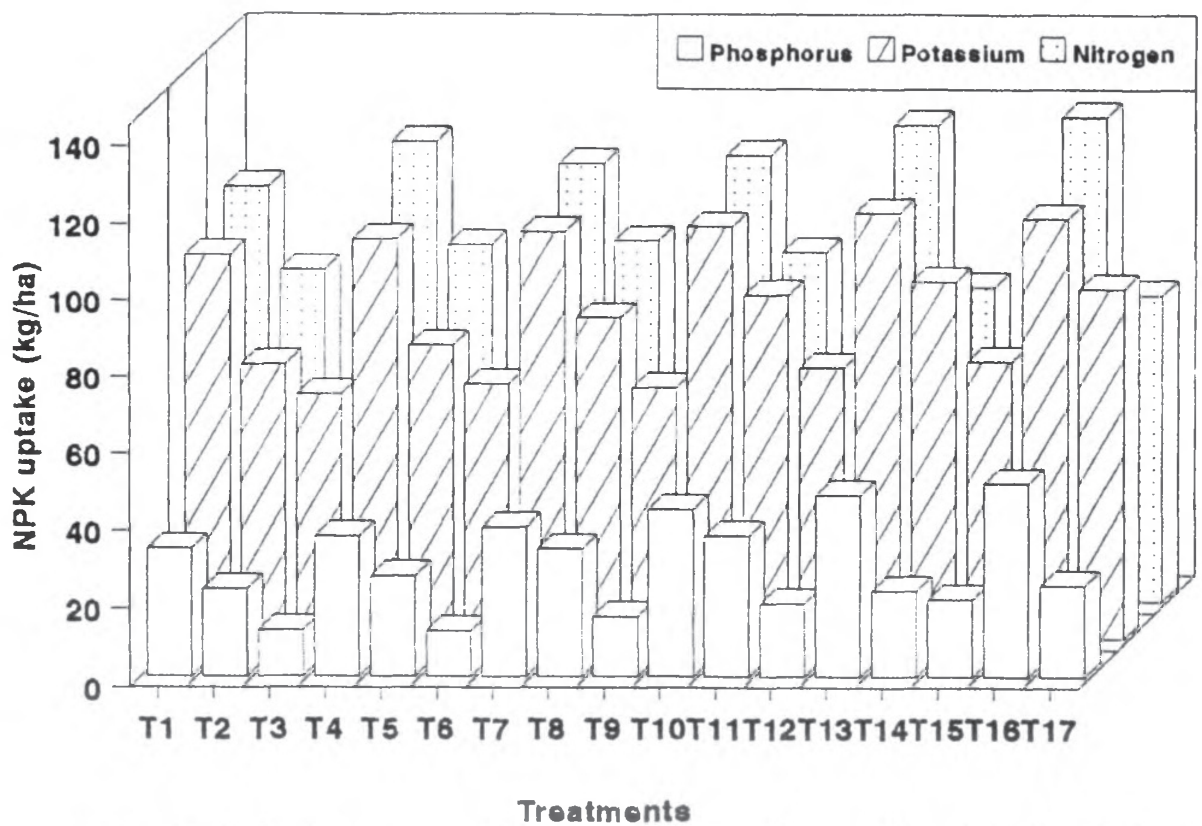

Fig. 9. Effect of integrated nutrient management on NPK uptake (kg/ha) by sunflower at harvest

4.5.1 *Electrical conductivity(dsm^{-1})*

The electrical conductivity (dsm^{-1}) did not vary due to different treatments imposed and the data are presented in Table 15.

4.5.2 *Organic carbon (%)*

The data on the organic carbon content of soil (%) as influenced by different treatments are presented in Table 15. Organic carbon content (%) of soil differed significantly due to various treatments. Application of FYM + 100 per cent RDF (T_4) recorded highest organic carbon content of 1.06 per cent than all other treatments except T_{13}, T_{17}, T_3 and T_{11} treatments.

Lowest organic carbon content was noticed in treatments receiving only 100 per cent RDF and 75 per cent RDF. However, these treatments were *on par* with T_{14}, T_{16} and T_{15} treatments.

4.5.3 *Available nitrogen*

Data pertaining to available nitrogen as influenced by different treatments are given in the Table 15 and Fig. 9. Application of PSM with either FYM or vermicompost and 100 per cent RDF (T_{13} and T_{16}) recorded significantly higher available nitrogen than all other treatments. Application of vermicompost + 100 per cent RDF (T_7) recorded significantly higher available nitrogen than all other treatments except T_{13} and T_{14}. Lowest available nitrogen was recorded in PSM + FYM (T_{12}) (166 kg/ha) than all other treatments and was *on par* with T_9, T_3 and T_{11} treatments.

4.5.4 *Available phosphorus*

Variation in available phosphorus was noticed due to different treatments and is presented in Table 15 and Fig. 9. Maximum available phosphorus(34.39 kg/ha) was noticed in PSM + FYM + 100 per cent RDF (T_{13}) was significantly superior to all

Table 15:Effect of integrated nutrient management on EC, Organic carbon(OC) and available N, P_2O_5 and K_2O at harvest of sunflower

Treatments	EC (dSm^{-1})	OC (%)	Available nutrients (kg/ha)		
			N	P_2O_5	K_2O
1. 100% RDF	0.11	0.67	205.37	25.14	316.30
2. 75% RDF	0.11	0.67	190.00	22.76	301.66
3. FYM @ 8 t/ha	0.10	0.95	172.34	26.89	285.00
4. FYM @ 8 t/ha + 100% RDF	0.10	1.06	206.00	31.89	344.71
5. FYM @ 8 t/ha + 75% RDF	0.12	0.90	202.00	21.46	338.41
6. Vermicompost @ 2 t/ha	0.10	0.74	187.67	26.27	331.25
7. Vermicompost @ 2 t/ha + 100% RDF	0.11	0.80	220.33	28.72	362.31
8. Vermicompost @ 2 t/ha + 75% RDF	0.11	0.84	190.00	28.11	319.84
9. PSM @ 375 g/ha	0.10	0.92	167.67	23.32	300.00
10. PSM @ 375 g/ha + 100% RDF	0.11	0.90	181.68	32.43	321.00
11. PSM @ 375 g/ha + 75% RDF	0.09	0.94	173.34	31.48	307.00
12. PSM @ 375 g/ha + FYM @ 8 t/ha	0.10	0.86	166.00	27.58	295.00
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	0.10	1.01	235.00	34.39	348.68
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	0.11	0.70	187.65	29.82	307.00
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	0.11	0.78	191.00	26.77	288.00
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	0.10	0.69	240.67	32.67	336.97
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	0.11	0.95	186.25	30.21	331.98
S.Em ±	0.01	0.04	2.80	1.36	10.00
CD(0.05)	NS	0.12	8.06	4.06	28.82

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism

LEGEND

T_1	100% RDF (60:75:60 NPK kg/ha)
T_2	75% RDF (45:56.25:45 NPK kg/ha)
T_3	FYM @ 8 t/ha
T_4	FYM @ 8 t/ha + 100% RDF
T_5	FYM @ 8 t/ha + 75% RDF
T_6	Vermicompost @ 2 t/ha
T_7	Vermicompost @ 2 t/ha + 100% RDF
T_8	Vermicompost @ 2 t/ha + 75% RDF
T_9	PSM @ 375 g/ha
T_{10}	PSM @ 375 g/ha + 100% RDF
T_{11}	PSM @ 375 g/ha + 75% RDF
T_{12}	PSM @ 375 g/ha + FYM @ 8 t/ha
T_{13}	PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF
T_{14}	PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF
T_{15}	PSM @ 375 g/ha + vermicompost @ 2 t/ha
T_{16}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 100% RDF
T_{17}	PSM @ 375 g/ha + vermicompost @ 2 t/ha + 50% RDF

RDF = Recommended dose of fertilizers
FYM = Farm yard manure
PSM = Phosphorus solubilising micro-organisms

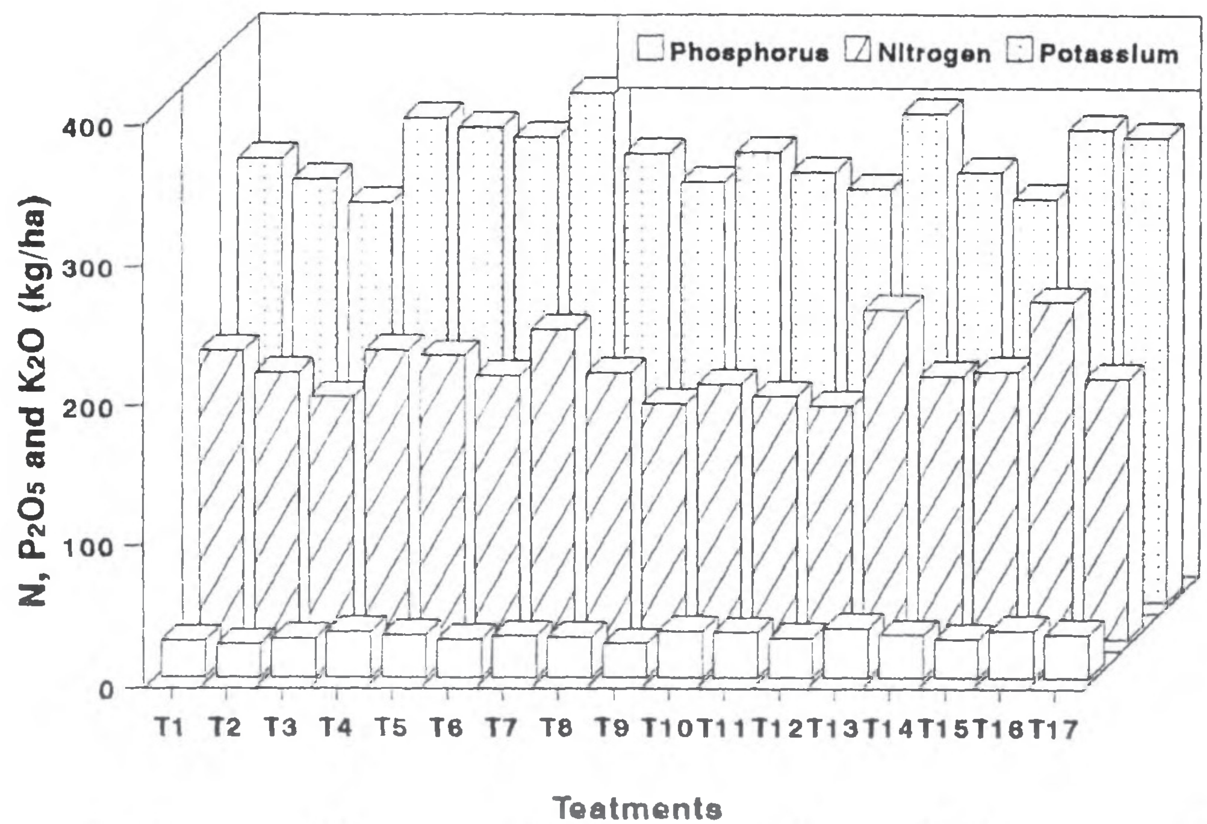

Fig. 9. Effect of integrated nutrient management on available N, P_2O_5 and K_2O at harvest of sunflower

other treatments except T_{16}, T_{10}, T_4 and T_{11} treatments. Maximum available phosphorus (22.76 kg/ha) was noticed in 75 per cent RDF (T_2) as compared to all other treatments and was *on par* with T_9, T_{11}, T_6, T_{15} and T_3 treatments.

4.5.5 Available potassium

The available potassium differed significantly due to different treatments and the data are given in Table 15 and Fig. 9. The maximum available potassium of 362.31 kg per hectare was observed in treatment receiving vermicompost + 100 per cent RDF (T_7) as compared to all other treatments and was *on par* with T_{13}, T_4, T_5 and T_{16} treatments. The available potassium was minimum (285 kg/ha) in FYM @ 8 tonnes per hectare (T_3) as compared to all other treatments except T_{15}, T_{12} and T_9 treatments.

4.6 ECONOMICS OF INTEGRATED NUTRIENT MANAGEMENT IN SUNFLOWER

The data pertaining to economics (cost of cultivation,gross income, net income and benefit cost ratio) of sunflower are presented in Table 16. Combined application of vermicompost in conjunction with PSM and 100 per cent RDF recorded highest cost of cultivation(Rs. 9992/ha) as compared to other treatments and it was followed by vermicompost + 100 per cent RDF (Rs. 9942/ha). The treatment receiving only PSM @ 375 g per hectare and PSM + FYM recorded the lowest cost of cultivation (Rs. 4025 and Rs. 5401/ha respectively).

The maximum gross income of Rs. 12756 per hectare was obtained from the treatment receiving PSM + FYM + 100 per cent RDF followed by PSM + vermicompost + 100 per cent RDF (Rs. 12097/ha) and lowest gross income of Rs. 4230 per hectare was obtained in the treatment receiving only PSM @ 375 g per hectare.

Table 16:Effect of integrated nutrient management on economics of sunflower

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
1. 100% RDF	5942	10412	4470	0.75
2. 75% RDF	5450	9140	3690	0.68
3. FYM @ 8 t/ha	5431	5178	-253	-0.05
4. FYM @ 8 t/ha + 100% RDF	7398	10925	3528	0.47
5. FYM @ 8 t/ha + 75% RDF	6906	10010	3104	0.45
6. Vermicompost @ 2 t/ha	7975	6328	-1647	-0.21
7. Vermicompost @ 2 t/ha + 100% RDF	9942	10981	1039	0.10
8. Vermicompost @ 2 t/ha + 75% RDF	9450	10456	1007	0.10
9. PSM @ 375 g/ha	4025	4230	205	0.05
10. PSM @ 375 g/ha + 100% RDF	5992	10814	4822	0.80
11. PSM @ 375 g/ha + 75% RDF	5500	10211	4711	0.85
12. PSM @ 375 g/ha + FYM @ 8 t/ha	5401	7165	1764	0.33
13. PSM @ 375 g/ha + FYM @ 8 t/ha + 100% RDF	7448	12756	5308	0.71
14. PSM @ 375 g/ha + FYM @ 8 t/ha + 50% RDF	5481	9899	4418	0.81
15. PSM @ 375 g/ha +Vermicompost @ 2 t/ha	8025	6562	1463	0.18
16. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 100% RDF	9992	12097	2105	0.21
17. PSM @ 375 g/ha +Vermicompost @ 2 t/ha + 50% RDF	9009	9508	499	0.05

RDF =Recommended dose of fertilizer(60:75:60 N, P_2O_5, K_2O kg/ha)
FYM = Farm yard manure
PSM = Phosphorus solubilising microorganism
B:C ratio = Benefit cost ratio

The Treatment receiving PSM + FYM + 100 per cent RDF and PSM + 100 per cent RDF have given maximum net return of Rs. 5308 and Rs. 4822 per hectare respectively. Not much difference in the net returns was seen among the treatments receiving only 50 per cent RDF along with PSM and FYM (Rs. 4418/ha) and treatment receiving only 100 per cent RDF (Rs. 4470/ha). There was loss of Rs. 253 and Rs. 1047 per hectare in T_3 and T_6 respectively.

Benefit cost ratio was maximum in treatment receiving PSM + 75 per cent RDF (0.85) followed by PSM + FYM+ 50 per cent RDF (0.81) while, the lower benefit cost ratio was recorded from T_9 and T_{17}.

4.7 CORRELATION STUDIES

The relationship between sunflower yield with growth and yield parameters have been worked out and the correlation coefficients are presented in Table 17. The relationship between seed yield of sunflower and leaf area per plant, dry matter production at 30, 60 DAS and at harvest, head diameter and thousand seed weight were found significant and positively correlated except per cent chaffiness which was significant but negatively correlated with seed yield.

Table 17: Correlation of sunflower seed yield with other characters

Correlation between seed yield and	Correlation coefficient
1. Leaf area cm2/plant at 60 DAS	0.96*
2. Dry matter production (g/plant) at 30 DAS	0.90*
3. Dry matter production (g/plant) at 60 DAS	0.97*
4. Dry matter production (g/plant) at harvest	0.95*
5. Head diameter (cm)	0.81*
6. 1000 seed weight(g)	0.87*
7. Per cent chaffiness	-0.92*

r = 0.48
* = Significant at 5 per cent

Discussion

V. DISCUSSION

Integrated nutrient management plays an important role in modern agriculture. Application of organic manures and biofertilizers in conjunction with chemical fertilizers improves the efficiency of nutrients and their uptake by crops. It improves the physico-chemical properties of soil and maintains a feasible soil-plant growth conditions, thus augments the crop yields. In view of this, the present investigation to study the effect of integrated nutrient management on sunflower was taken up during *rabi/summer* 1996. The results obtained in the above investigation are discussed in this chapter.

5.1 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF SUNFLOWER

In the present study there existed significant difference in the seed yield of sunflower with different treatment combinations (Table 13). The highest seed yield of 1143 kg per hectare was observed in the treatment receiving PSM + FYM + 100 per cent RDF (T_{13}). Though maximum seed yield was recorded with this treatment it was *on par* with PSM + vermicompost + 100 per cent RDF (T_{16}) treatment where a seed yield of 1084 kg per hectare was obtained. The increase in yield with these two treatments over 100 per cent recommended dose of fertilizer (T_1) was 12.47 and 16.18 per cent respectively. The present results are in conformity with the findings of Dzanagov and Gizoev (1980), Sathiyavelu *et al.* (1994) and Venkatakrishnan andBalasubramaniam (1996). Several other workers also reported increased yield of field crops due to combined application of organic manures in conjunction with chemical fertilizer (Badanur and Tolanur, 1992 in safflower Manjaiah et al., 1996 in groundnut).

The significant increase in seed yield with combined application of PSM + FYM + 100 per cent RDF and PSM + vermicompost + 100 per cent RDF over other treatment combinations may be attributed to the significant increase in the head diameter, total number of seeds per head and thousand seed weight (Table 12). These results are in agreement with findings of Manjaiah *et al.* (1996) and

Venkatkrishnan and Balasubramaniam (1996) in groundnut and sunflower crops respectively.

The increase in yield and yield attributing characters with the application of farm yard manure may be attributed to the fact that the added FYM acts as the store house of several macro and micronutrients, which are released during the process of mineralization. In addition to release of plant nutrients from the organic matter the organic acids formed in the process also release the available plant nutrients present in the soil and increases the fertilizer use efficiency. Thus FYM might have stimulated the activity of micro organisms that make the plant-food elements in the soil readily available to the crops (Dahama 1996). Moreover, FYM seems to act directly in increasing crop yields either by acceleration of respiratory process by increasing cell permeability, by harmone growth action or by combination of all these processes. The beneficial effect of FYM on sunflower is well documented by several workers (Matherl and Stewart, 1982; Govi *et al.*, 1988; Awad and Geeresh 1992: Sathiyavelu *et al.*, 1994 and Raghbir Singh *et al.*, 1996).

The increase in yield and yield attributing characters with the application of vermicompost may be the result of higher amount of available major and minor nutrients present in vermicompost treated plots. Apart from the above mentioned characters, vermicompost harbours rich amount of microbes that degrade and mobilize the nutrients to available form, since exudates of earthworms support the growth of micro-organisms which secrete plant growth harmones, these organisms are also found to fix atmospheric nitrogen into available nitrogen to the plants (Lee, 1992). The vermicompost is an aerobically degraded organic matter which has undergone chemical disintegration by the associated microbial population (Kale et al., 1992). The beneficial effect of vermicompost on crops has been reported by various workers (Saciragic and Dzelilovic, 1986 in cabbage: Kale et al., 1994 in sunflower, groundnut and soybean and Vasanthi and Kumaraswamy, 1996 in rice).

Only ten to fifteen percent of applied phosphorus becomes available for the plants and remaining portion of phosphorus is converted into unavailable form, thus fixed phosphorus can be solubilized by the special group of micro-organisms. The phytase enzymes produced by the micro-organisms will help in solubilizing this fixed phosphorus. The beneficial effect of P-solubilizers might be due to enhanced root growth and in turn better uptake of nutrient and may also be due to the production of growth promoting substances like auxins and gibberlins besides phosphate solubilization (Piccini and Azcon,1987). The significant increase in the seed yield and attributes of sunflower may be due to the favourable effects of phosphorus solubilizing micro-organisms (PSM) as enumerated above.

It is interesting to note that the seed yield of sunflower obtained due to combined application of PSM + FYM + 50 per cent RDF and PSM + vermicompost + 50 per cent RDF was *on par* with the seed yield obtained with the application of 100 per cent RDF alone (Table 13). The above results indicated that the application of only 50 per cent RDF would be sufficient to the nutrient requirements of the crop at the later growth stages. Incorporation of organic manures enhance the efficiency of the added inorganic fertilizers and thus increases the yield. It is clearly evident from the above results that with the application of organic source of nutrients it is possible to save 50 percent cost on chemical fertilizers without reduction in yield.

Lower seed yield of sunflower was in the treatment where organic source of nutrient alone was applied. Significantly lower seed yield of 379 kg per hectare was observed in the treatment receiving PSM @375 gm per hectare (T_9) alone and was *on par* with FYM @ 8 tonnes per hectare (T_3) and vermicompost @ 2 tonnes per hectare (T_6). Significant reduction in seed yield of sunflower obtained due to the application of only organic source of nutrients over combined application of organic sources in conjunction with inorganic fertilizers might be due to lower nutrient availability in soil, which resulted in the less uptake of nutrients by the crop, which lead to decreased growth components, yield components and yield of sunflower. This is attributed to lower leaf area, lesser total dry matter production and its accumulation in different plant parts, lesser CGR, RGR and NAR (Table 9 and 10) during 30-60 DAS. The observations are in line with the findings of Venkatakrishnan and Balsubramaniam (1996).

The increase in yield and yield attributing characters with conjuctive use of organic manures and PSM treatments may be due to production of higher total dry matter over all other treatments. Significantly higher total dry matter production of 68.24 g per plant was observed in the treatment T_{13} receiving PSM FYM + 100 per cent RDF and was *on par* with PSM + vermicompost + 100 per cent RDF (63.39 g/plant). The increase in total dry matter production in these two treatments over 100 per cent RDF alone (60.94 g/plant) was 11.98 and 4.02 per cent respectively. The total dry matter produced with PSM + FYM + 50 per cent RDF (55.73 g/plant) treatment was *on par* with 100 per cent RDF (60.94 g/plant). Similar results were reported by Manjaiah *et al.* (1996) in groundnut.

A significant positive correlation (r = + 0.95) was observed between dry matter production at different stages of crop growth and seed yield per hectare(Table-17). A possible explanation that could be given here is that, combined application of FYM or vermicompost with PSM and 100 per cent RDF resulted in higher photosynthetic capacity as well as sink capacity. Consequently there was higher total dry matter production and its accumulation in seeds.

The total dry matter production and its accumulation in different plant parts depends upon photosynthetic capacity of plant during seed filling stage. Photosynthetic capacity of plant depends upon dry matter accumulation in leaves, leaf area and leaf area index. Difference in dry matter production and accumulation in different plant parts may be traced back to difference in growth functions. Crop growth rate and leaf area duration significantly differed due to combined application of organic manures with PSM and 100 per cent RDF (Table 5). During 30-60 DAS higher relative crop growth rate (RGR) and net assimilation rate (NAR) was also noticed (Table 10). This suggests the ability of FYM or vermicompost to nourish the crop with adequate amount of nutrient (Kale *et al.,* 1994). Probably, the application of these organic manures resulted in the development of the efficient photosynthetic system, which enabled the plant to intercept higher quantities of radiant energy with the larger leaf surface area and converted into chemical energy resulting in higher accumulation of dry matter per plant, early initiation and greater development of reproductive system.

Head diameter, number of filled seeds and thousand seed weight (Table 11 and 12) was significantly higher in treatment receiving PSM + FYM + 100 per cent RDF (T_{13}) and PSM + vermicompost + 100 per cent RDF (T_{16}). These results are in agreement with the findings of Venkatakrishnan and Balsubramaniam, (1996). Several other workers also reported similar results in other crops (Hebbara, 1987; Manjaiah, 1989 in groundnut and Stephens et al., 1994 in wheat). Combined application of organic manures and PSM had beneficial effect in increasing the seed yield of sunflower, suggesting that they had cumulative influence in increasing the yield of sunflower and can save 50 per cent of inorganic fertilizers through these organic source of nutrients.

5.2 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON NUTRIENT UPTAKE BY SUNFLOWER

The growth and yield of crop plants are determined by the presence of sufficient quantities of nutrients in the soil in available form for plant uptake (Babannavar, 1990). The higher yield of sunflower in the present study due to combined application of PSM and FYM with 100 per cent RDF and yield obtained due to the application of PSM + vermicompost + 100 per cent RDF can be assigned to the increased nutrient availability and their uptake by the crop (Table 14 and 15). Application of PSM and vermicompost in combination with 100 per cent RDF had significant influence on the N uptake by plants (125.9 kg/ha) which was 16.88 per cent higher over 100 per cent RDF alone. The increase in N uptake due to application of PSM and vermicompost can be ascribed to increased phosphorus availability to the crop. Phosphorus is known to increase the root growth and proliferation (Nelson and Tisdale, 1968) thereby creating more absorptive area for uptake of other nutrients specially the nitrogen. Puntamkar and

Bhathkal (1967) obtained increased uptake of nitrogen at all the stages of crop growth and this was attributed to the application of phosphorus and their synergetic interaction, which gain support from the results of present investigation.

The increased nitrogen uptake by the crop due to vermicompost can also be ascribed to the presence of higher activity of N fixers, mycorhizae in rhizosphere which inturn probably increased the uptake of nutrients by means of altering the root surface characteristics involved in nutrient uptake (Kale *et al.*, 1994).

The same argument may hold true for the increased phosphorus uptake by sunflower crop due to combined application of PSM and vermicompost with 100 per cent RDF as compared to only 100 per cent RDF, where the P uptake was only 32.56 kg per hectare.

Application of PSM + vermicompost + 50 per cent RDF recorded on par P uptake (23.29 kg/ha) with 100 per cent RDF. The per cent increase in the P uptake due to the application of PSM + vermicompost + 100 per cent was 52.13 per cent over application of only 100 per cent RDF (Table 14). The inoculated phosphorus solubilizing micro-organism established well in the rhizosphere. increased the available phosphorus in soil thereby increasing its uptake by the crop. These findings are in line with the results of Kundu and Gaur, (1980); Maurya and Sanoria (1982); Rachewad *et al.* (1992); Jisha and Alagawadi (1996) who observed increased P uptake in potato, chickpea, sunflower and sorghum crops respectively due to inoculation with P solubilizing organisms.

Similar trend was observed with regard to potassium uptake. In the present investigation, the potassium uptake by sunflower crop was maximum due to combined application of PSM and FYM or vermicompost with 100 per cent RDF (Table 14).

5.3 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PROPERTIES

A perusal of soil analysis data after harvest of sunflower crop revealed that organic carbon content in soil increased significantly due to the application of organic source of nutrients in conjunction with inorganic fertilizers as compared to inorganic source of nutrient alone (Table 15). This may be ascribed to enhanced microbial activity and increased rate of decomposition of organic manures in the presence of added nutrients.

The combined application of PSM and vermicompost with 100 per cent RDF had significantly influenced on the available NPK content of soil as compared to application of inorganic fertilizers alone (Table 15). However, it was *on par* with PSM + FYM + 100 per cent RDF (T_{13}). The increase in available N content in soil can be attributed to the supply of available nitrogen to available soil nutrient pool through these organics during decomposition process (Aziz Qureshi, 1991).

The increase in available phosphorus content in soil due to combined application of PSM + FYM + 100 per cent RDF (34.39 kg/ha) can be ascribed to the organic acid production, carbon dioxide liberation and the additional P content in added organic materials (Dhillon and Dev, 1986). Significantly higher available phosphorus of 30.21 kg per hectare was recorded in the treatment (T_{17}) PSM + vermicompost + 50 per cent RDF and 29.82 kg per hectare in the treatments (T_{14}) PSM + FYM + 50 per cent RDF over application of 100 per cent RDF (25.14 kg/ha). The increase in available phosphorus with these two treatment over 100 per cent RDF alone (T_1) was 20.16 and 18.61 per cent respectively. The released organic acids from organic materials are capable of improving the dissolution of added phosphorus and release of phosphorus that was associated with clay minerals (Tomark *et al.*, 1984).

Similar trend was observed with regard to potassium content in the soil under present investigation. The available K content in soil was maximum with combined application of PSM, FYM and 100 per cent RDF. Application of PSM + vermicompost (Table 15) or FYM (T_{16} and T_{13}) with only 50 per cent RDF recorded *on par* available K in soil as that of 100 per cent RDF alone. It may be due to the increased K content in soil because of improved soil condition due to addition of organic materials. The organic acids or organic chelates released by phosphorus solubilizers or decomposition of organic materials, readily released P from added phosphorus and this in turn made K more available. Similar observations were made by Olsen *et al.* (1970) and Manjaiah *et al.* (1996).

5.4 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON ECONOMICS IN SUNFLOWER

Economics of organic sources of nutrients and chemical fertilizer application to sunflower indicated that the total net returns with PSM + FYM + 100 per cent RDF and PSM + 100 per cent RDF were Rs. 5308 and Rs. 4822 per hectare respectively. The higher net returns in these treatments were mainly because of their lower cost and subsequently lower cost of cultivation. Benefit cost ratio in vermicompost @ 2 tonnes per ha was lower (-0.21) than other treatments. The lower Benefit Cost ratio in vermicompost applied treatments were mainly because of its higher cost and subsequently higher cost of cultivation and consequently reduced the net returns. The benefits interms of higher seed yield, improvement of soil physico-chemical properties and the biological properties should not be over looked, inspite of lower benefit cost ratio in vermicompost treated plots. By producing vermicompost at farm level with available organic residues, cost of vermicompost could be lowered considerably. In the present investigation it was observed that application of PSM + FYM + 50 per cent RDF recorded higher benefit cost ratio (0.81) when compared to application of 100 per cent RDF (0.75) alone. It indicates that with the application of PSM + FYM + 50 per cent RDF, 50 per cent of fertilizers (N, P and K) could be saved without reducing the monetory returns.

5.5 PRACTICAL UTILITY OF THE RESULTS.

The present investigation generated following results of practical utility.

1. Among the organic sources of nutrients in conjuction with 100 per cent RDF tested in the present study, application of FYM + PSM + 100 per cent RDF showed superiority with respect to seed yield (1143 kg/ha) followed by PSM + vermicompost + 100 per cent RDF (1084 kg/ha).
2. Combined application of PSM + FYM + 100 per cent RDF showed superiority with respect to net returns (Rs 5308/ha) followed by PSM + 100 per cent RDF (Rs 4822/ha).
3. Application of PSM and FYM with only 50 per cent RDF produced on par yield as compared to application of 100 per cent RDF. It shows that 50 per cent of cost on chemical fertilizers could be reduced without affecting the seed yield.
4. Applied organic sources of nutrients, beside increasing the fertilizer use efficiency also improved the nutrient status of soil. Application of FYM + PSM + 100 per cent RDF increased the available N(235 kg/ha), P_2O_5(34.39 kg/ha) and K_2O (348.68 kg/ha) over other treatments tested.

5.6 Future line of work

1. Information pertaining to the residual effect of vermicompost and PSM on succeeding crops is meagre which needs to be studied.
2. Response of sunflower to vermicompost at different plant population levels needs to be studied.
3. In depth studies on time, dose and methods of application of PSM to sunflower alone and along with FYM or vermicompost and different doses of fertilizers are required for different soils for increasing the crop yields.
4. Practices for production of vermicompost at cheaper rate are to be found out to reduce the cost of cultivation with vermicompost.

Summary

VI.SUMMARY

A field experiment was conducted at Regional Research Station, Raichur during *rabi/summer* season of 1996, under irrigation to study the effect of different organic manures, biofertilizers and fertilizers on growth, yield components, oil content and yield of sunflower. The experiment was replicated three times in a randomised block design. The important findings of this investigations are summarised here.

Combined application of organic manures, biofertilizers in conjuction with inorganic fertilizers increased the yield significantly. The treatment which received PSM + FYM + 100 per cent RDF (T_{13}) recorded significantly highest seed yield of 1142 kg per hectare, and it was *on par* with T_{16} treatment receiving PSM+vermicompost (1084 kg/ha) and these two treatments were significantly superior over 100 per cent RDF. Application of only 50 per cent RDF in conjunction with vermicompost or FYM and PSM recorded on per yield with 100 per cent RDF. The increase in the seed yield may be due to higher yield components like head diameter, number of filled seeds per head and thousand seed weight. These were influenced by the total dry matter production per plant. This increased dry matter production may be the consequence of higher photosynthetic efficiency noticed in the combined application of organic manures, biofertilizers in conjuction with inorganic fertilizer as evidenced by increased leaf area per plant, leaf area duration and crop growth rate.

Significantly higher plant height, leaf area and leaf area index were recorded in treatments which received PSM + FYM or vermicompost+100 per cent RDF when compared to other treatments. Total dry matter production and its distribution in head, leaves and stem were also higher with the combined application of organic and inorganic fertilizers inoculated with p-solubilizers. Significantly higher total dry matter production was recorded in T_{13} and T_{16} treatment as compared to T_1 treatment which received only 100 per cent RDF. Significantly lower seed yield of 379 kg per hectare was noticed in treatment which received only PSM @ 375 g per hectare (T_9) and was *on par* with T_3 and T_6 treatments.

Number of filled seeds per head and thousand seed weight differed significantly. The highest filled seeds of 432.60 and thousand seed weight of 54.81 g was recorded in treatment T_{13} and was *on par* with T_{16} treatment. Stalk yield, oil yield and harvest index was highest with application of PSM + FYM + 100 per cent RDF (T_{13}) treatment, which was *on par* with PSM + vermicompost + RDF (T_{16}) treatment. Non significant differences in oil content was noticed within the treatments, however numerically highest oil content of 41.9 per cent was recorded in T_{13} treatment.

Significant differences in the uptake of N, P, and K were observed. Highest uptake was noticed in treatment receiving organic source of nutrient in conjuction with chemical fertilizers. Significantly higher uptake of N(125.59 kg/ha), P(49.56 kg/ha) and K(109.16 kg/ha) was noticed in T_{16} than all other treatments except T_{13} treatments and was *on par* with it.

Application of FYM or vermicompost and PSM with 100 per cent RDF (T_{13} and T_{16}) recorded significantly higher available N, P_20_5, and K_20 in soil after the harvest of sunflower. Organic carbon content in soil after the harvest of crop was highest in T_4 treatment and was *on par* with T_{13} and T_{16} treatments. However the electrical conductivity did not differ significantly among the treatments.

Cost of cultivation in the treatment involving vermicompost application was higher due to higher cost of vermicompost. However, highest net returns were obtaind with PSM + FYM + 100 per cent RDF and PSM + 100 per cent RDF followed by 100 per cent RDF and PSM + FYM + 50 per cent RDF, while, lowest net returns were recorded in treatment receiving vermicompost alone applied @ 2 tonnes per hectare.

Highly significant positive correlations were noticed between seed yield and total dry matter at various stages of crop growth, leaf area at 60 DAS, head diameter and thousand seed weight. Significantly negative correlation was noticed between seed yield and per cent chaffiness.

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Appendix

APPENDIX - I

Particulars	Prices (Rs.)
1. Sunflower seeds (CMS 234B)	52.00 /kg
2. Urea	340.00 / q
3. Diammonium phosphate	830.00/q
4. Muriate of potash	340.00/q
5. FYM	160.00/t
6. Vermicompost	2000.00/t
7. Marketing and handling charges	2 % of the gross value of produce
Output	
Sunflower seeds	1116.00/q