"EFFECT OF PHOSPHORUS AND PLANT GROWTH REGULATORS ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"

BY

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B.Sc. (Hort.)

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CERTIFICATE

G. C. GANGARAM has satisfactorily prosecuted the course of research and that the thesis entitled **"EFFECT OF PHOSPHORUS AND PLANT GROWTH REGULATORS ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Place: Rajendranagar

(Dr. S. S. VIJAYA PADMA)
MAJOR ADVISOR

Date:

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF PHOSPHORUS AND PLANT GROWTH REGULATORS ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"** Submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN HORTICULTURE**, for **Andhra Pradesh Horticultural University, Venkataramannagudem,** is a record of the bonafide research work carried out by Mr. **M. PHANIKRISHNA** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

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Rajendranagar **(G. C. GANGARAM)**

June, 2011

DECLARATION

I, Mr. G. C. GANGARAM, hereby declare that the thesis entitled **"EFFECT OF PHOSPHORUS AND PLANT GROWTH REGULATORS ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"**

Submitted to **ANDHRA PRADESH HORTICULTURAL UNIVERSITY** for the Degree of **MASTER OF SCIENCE IN HORTICULTURE** is a result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Place: Rajendranagar **(G. C. GANGARAM)**

Date:

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ABBREVIATIONS USE IN TEXT

/	:	Per
@	:	At the rate of
%	:	Percentage
ANOVA	:	Analysis of variance
B: C	:	Benefit cost ratio
C.D	:	Critical difference
cm.	:	Centimeter
^{0}C	:	Degree Celsius
cv.	:	Cultivar
D.F.	:	Degree of Freedom
DAP	:	Dia Ammonium Phosphate
DAS	:	Days after sowing
et.al	:	and others

Fig.	:	Figure
&	:	and
g	:	Gramme
GA	:	Giberellic acid
ha.	:	Hectare
HI	:	Harvest index
Hr	:	Hour
i.e.	:	That is
A.P.H.U.	:	Andhra Pradesh Horticultural University
K	:	Potassium
Kg	:	Kilogram
Kg/ha	:	Kilogram per hectare
Max.	:	Maximum
Min.	:	Minimum
mg.	:	Milligram
MOP	:	Murate of potash
M.S.S	:	Mean sum of square
m. sq.	:	Meter square
NAA	:	Naphthalene acetic acid
No.	:	Number
NS	:	Non significant
P_2O_5	:	Phosphorus
PGR	:	Plant Growth Regulator
ppm	:	Part per million
R.H.	:	Relative humidity
Rs.	:	Rupees
r	:	Coefficient of correlation
SEm	:	Standard Error of Mean
Sig.	:	Significant
q/ha	:	Quintal per hectare
Viz.	:	(Videlicet) Namely

Name of the student	: **G. C. GANGARAM**
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ABSTRACT

A field experiment entitled "Effect of phosphorus and plant growth regulators on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.)" was carried out at Model orchard, College of Horticulture Rajendranagar during the *rabi*, 2010-11.

The significant effect of the phosphorus were observed for plant height 50.13, number of branches 5.38, fresh weight of plant 2610.29, dry weight of plant 649.96, number of pods per plant 26.21, number of seeds per pod 15.02, test weight 13.08, seed yield 15.91, straw yield 42.12, biological yield 55.68, protein content of seed 21.41, and chlorophyll content of leaves at both stages 1.52. However highest N, P, K content of seed was observed with RDF.

The significant effect of plant growth regulators were observed for plant height 51.96 and days to 50 % flowering 42.66 maximum with the treatment 50 ppm GA_3, were minimum with the treatments 75 ppm Ethrel.

The significant effect of plant growth regulators were observed for higher number of branches with 75 ppm Ethrel.

Among the different treatment combinations, plant growth regulators and phosphorus were observed for number of branches , number of pods per plant, number of seeds per pod, test weight, seed yield, straw yield, biological yield, N, P, K content of seed, protein content of seed, and chlorophyll content of leaves was observed in 60 kg phosphorus with 20 ppm NAA.

Among the different treatment combinations, plant growth regulators and phosphorus application of at 60 kg phosphorus with GA_3 50ppm had significant effect on plant height at 30, 60 DAS and at harvest with a mean maximum 12.00 cm, 37.21 cm and 56.64 cm, while minimum observed was 10.58 cm, 26.58 cm and 40.68 cm with application of 20 kg phosphorus with Ethrel 75 ppm at 30, 60 DAS and at harvest respectively.

The highest cost benefit ratio was obtained with the treatment “60 kg Phosphorus /ha with 20 ppm NAA”.

The worked out economics revealed that, the maximum revenue (Rs.8692/ha) and net profit (Rs.32096/ha) were obtained from 60 kg phosphorus/ha with 20 ppm NAA.

CHAPTER I

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual spice crop. Both leaves and seeds are extensively used for medicinal purposes. Recent studies indicate that fenugreek seeds contain the steroidal substance diosgenin substantial quantity.

Fenugreek is considered to have originated in South-Eastern Europe and far West Asia. India is one of the major producer, consumer and exporter of fenugreek. In India during 2006-07, fenugreek was cultivated on 1208 thousand hectares with an annual production of 27.78 thousand tonnes. Rajasthan and Gujarat are the major states producing methi as seed. Export of fenugreek was 17,000 tonnes and the value of export was Rs 6,168.10 lakhs during the year April-february 2010-11 and accounting for 3.60% in total spice exports from India.

Soil of India is low to medium in available phosphorus. The fertilizer use efficiency of phosphatic fertilizers is very low (20-25%) due to chemical fixation in soil. Phosphorus deficiency is usually the most important single factor, which is responsible for poor yield in legume crops on all types of soil. The role of plant growth regulators in enhancing the production of crop has been recognized and now this low cost technology has emerged as a boon for enhancing the agricultural production at an unprecedented rate and in a short duration crop like methi it will be very advantageous. It has been observed that synthesis and translocation of photosynthates into sink is very poor at later stages of the crop, besides poor vegetative growth and flowering. Growth hormones play an important role as they regulate the various physiological processes and source - sink balance thereby increasing the productivity.

Gibberellic acid (GA_3) has been used in increasing stalk length, vegetative growth, flower initiation, increasing fruit size, hastening maturity, improving fruit quality, controlling fruit cracking and yield in fenugreek (Deore and Bharud, 1990; Badge *et al.*, 1993) in horticultural crops. GA_3 plays an important role in enhancing the growth and development and yield.

Auxin works as stimulator for cell division and cell enlargement in apical region. It enhances the nucleic acid activities, flowering, fruit set, fruit retention and fruit quality of various horticultural crops.

Use of plant growth regulator towards higher productivity and improvement in quality in fenugreek is an area of interest. Plant growth regulators like GA_3 and Ethrel react favorably with different seed spices when applied judiciously (Khateeb, 1994 and Alhadi *et al.*, 1998 and Keltawani *et al*., 2000).

In the light of above cited facts, lack of information on these aspects with respect to fenugreek and considering the importance of fenugreek for human health and national economy, the present investigation entitled "Effect of phosphorus and plant growth regulators on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.)" is envisaged with the following objectives,

Objectives

1. To study the effect of phosphorus on growth, yield attributes, yield and quality of fenugreek.
2. To study the effect of different levels of plant growth regulators on growth, yield attributes, yield and quality of fenugreek.
3. To work out the economics of different treatments.

CHAPTER II

REVIEW OF LITERTURE

Tremendous research work has been done to increase the productivity of fenugreek, but the average yield in Madhya Pradesh and India is still far below the world average. The literature pertaining to the "Effect of phosphorus and plant growth regulators on growth, yield and quality of fenugreek" is briefly given below. In this chapter, due to the paucity of the adequate experimental evidences on these aspects, the similar work done on other crops has also been reviewed to understand the effect of different treatments.

2.1 Effect of phosphorus

Pareek and Gupta (1981) reported that the application of 30 kg N and 60 kg P_2O_5 per ha gave higher grain yield of fenugreek on a poor sandy loam soil. But the diosgenin content reduced from 0.35 per cent in the original bulk seed to 0.12 and 0.04 per cent in the first and second year of cultivation without fertilization and to still lower levels with N and P treatments.

Mandal and Maiti (1992) conducted the trail with fenugreek consisting four levels of N (0, 20, 40, 60 kg/ha) and five levels of P_2O_5 (0, 20, 40, 60, 80 kg/ha). Total P_2O_5 and half of N were applied in two split doses at the time of land preparation and six weeks after sowing. The better growth of plant and higher production of seed was obtained with 40 kg N (13.79 q/ha) and 60 kg P_2O_5/ha (14.49 q/ha). Number of fruits per plant increased significantly up to 60 kg P2O5/ha while number of seeds per pod and 1000 seed weight marginally increased up to 60 kg P_2O_5 per ha.

Baboo and Sharma (1995) reported that application of P_2O_5 @ 80 kg/ha gave markedly higher seed yield over lower rate of phosphorus. The protein and phosphorus content in seed was noted significantly higher with N 25 kg/ha plus inoculation of 80 kg P_2O_5/ha.

Mert *et al.* (1997) study was conducted in Turkey during winter 1994-95 to investigate the effects of nitrogen and phosphorus, each at 0, 3, 6 and 9 kg/ha on seed yield and yield components as well as essential oil content and yield of coriander (*Coriander sativum*). Plant height, number of branches per plant, number of umbels per plant, seed and essential oil yields increased with increasing N application. Increasing phosphorus rate up to 9 kg/ha had no significant effect on number of umbels per plant and seed yield. The highest seed yield (246.51 kg/ha) was obtained from the application of 9 kg N with 3 kg P/ha. The highest essential oil yield was recorded from the application of 9 kg N/ha.

Jat *et al.* (1998) reported that application of phosphorus 40 kg/ha significantly increased the number of pods per plant, number of seeds per pod, seed and straw yield of fenugreek cv. Rmt-1. It also significantly increased N content in grain and its uptake.

Kumar *et al.* (1999) reported that the number of branches and pods per plant, seed per pod, 1000 seed weight as well as seed and stover yield of fenugreek increased by phosphorus application significantly in all the three seasons.

Kumar *et al.* (2000) worked on irrigation and phosphorus requirements of fenugreek. The optimum doses of phosphorus were worked out as 27.8 kg/ha for no irrigation, 44.0 - 45.6 kg/ha for 2 irrigations at 45 or 80 days and 55.6 kg/ha for 2 irrigation. The responses of phosphorus on yield and phosphorus utilization efficiency at optimum doses increased with irrigation. Water use efficiency was improved by phosphorus application.

Naghera *et al.* (2000) observed that the effect of different nitrogen (N) and phosphorus (P) rates on coriander cv. Gujarat Coriander-2. Sowing on 30 October recorded the highest seed (905 kg/ha) and stick yields (1070 kg/ha), seed oil content (18.19%), net monetary return (Rs. 4743/ha), the tallest plant, highest number of branches and umbels per plant and the heaviest seed weight compared to sowing on 15 october and 15 november. Earlier sowing (15 October) recorded a 14% lower seed yield and 26% lower stick yield and delayed sowing (15 November) recorded a 12% lower seed yield and 22% lower stick yield than sowing on 30 October. Treatment with 40 kg N/ha recorded 19.6 and 4.0% more seed yield than treatment with 20 and 60 kg N/ha.

Ram and Verma (2000) reported that the phosphorus applied @ 52.8 kg/ha gave significantly higher seed yield and yield attributing characters such as weight of pods, seeds / plant, number of seeds / pod, weight of seeds / pod and test weight of 100 seeds.

Jat *et al.* (2003), reported that the maximum yield of fenugreek was recorded with the application of 80 kg P_2O_5 /ha, 100 kg S/ha and seed treatment with Rhizobium + PSB. The highest mean returns (Rs. 12137/- and B:C ratio (3.95) was recorded in fenugreek + pearl millet cropping sequence with 80 kg P_2O_5/ha, 100 kg S/ha and seed inoculation with Rhizobium + PSB in fenugreek

Satpal Singh Jat (2002) observed increase in plant height, dry matter, number of branches and umbels per plant, number of seed per umbel, and seed and stover yield with increasing rates of P_2O_5 and Zn in Rcr-41 cv of coriander when the effects of the interaction between P_2O_5 and Zn were significant

Khiriya and Singh (2003) conducted a field trial during two consequent *rabi* seasons with two fenugreek cvs HM 65 and NLM. The four levels of farmyard manure (0, 5, 10 and 15 tonnes/ha) and four levels of Phosphorus (0, 20, 40 and 60 kg/ha) were used. Each successive dose of FYM up to 15 tonnes/ha significantly increased the number of branches, pods / plant, seeds / pod, seed, straw and biological yields and nutrient uptake over their lower doses. Increasing levels of phosphorus up to 40 kg P_2O_5/ha significantly increased the yield attributing characters, seed yield and quality parameters of fenugreek.

Oliveira *et al.* (2004) reported that the effect of P_2O_5 on the yield of coriander [*Coriandrum sativum*] cv. Verdao. P_2O_5 was applied at 0, 50, 100, 150 and 200 kg/ha. The highest plant height (63 cm) and green mass (51 t/ha) was obtained with 93 and 112 kg P_2O_5/ha, respectively. P_2O_5 was the most economically efficient and produced the highest green mass yield (50.55 t/ha) with an increase of 15.1 t/ha.

Bhunia *et al.* (2006) reported that application of 40 kg P_2O_5 / ha significantly increased the yield attributes, viz. branches / plant, pods / plant, pod length, seeds / pod, test weight and the yield (8.08 q/ha) over 20 kg P_2O_5 / ha. Phosphorus at 40 kg P_2O_5 / ha gave the highest benefit : cost ratio (1.47) in comparison with 20 kg P2O5 / ha (1.42) and 60 kg P_2O_5 / ha (1.42). Application of P increased the N, P and K uptake up to 40 kg P_2O_5 / ha.

Nehara *et al.* (2006) conducted a field trial to study the response of fenugreek under different levels of phosphorus (0, 25 and 50 kg P_2O_5 / ha) and plant growth regulators (control, triacontanol 2 ppm, naphthaline acetic acid 20 ppm and ethephon 100 ppm). Increase in P_2O_5 level up to 50 kg/ha significantly increased the yield attributing characters (seed, straw and biological yields) and the net returns of fenugreek. The N and P contents of fenugreek in seed and straw and their total uptake increased significantly with increase in the level of applied phosphorus up to 50 kg/ha, except the P content in seed and straw, where significant increase was recorded only up to 25 kg P_2O_5 / ha. Among different growth-regulators, the application of NAA @ 20 ppm proved to be significantly better than the control, triacontanol and ethephon.

Tripathi (2006) observed the effects of NPK rates (0:0:0, 40:20:10, 60:30:15 or 80:40:20 kg/ha) on the performance of 4 coriander (*Coriandrum sativum*) cultivars (JD-1, UD-20, GWL-5365-91 and CS-208). Among the cultivars, JD-1 registered the highest values for yield (21.5 quintal/ha); N (56 kg/ha), P (35 kg/ha) and K (64 kg/ha) uptake; and available N (182 kg/ha), P_2O_5 (20 kg/ha) and K_2O (386 kg/ha). Among the fertilizer rates, NPK at 60:30:15 and 80:40:20 kg/ha were superior with regard to yield (22.1 and 22.5 quintal/ha), and N (51 and 57 kg/ha, respectively), P (29 and 37 kg/ha) and K (60 and 68 kg/ha). The highest levels of available N (196 kg/ha), P_2O_5 (21 kg/ha) and K_2O (395 kg/ha) were obtained with NPK at 80:40:20 kg/ha.

Ashok Kumar and Ranbir Singh (2007) observed that the performance of fenugreek under different P (control, 50 kg P_2O_5, 25 kg P_2O_5+phosphorus solubilizing bacteria (PSB), 25 kg P_2O_5+vescicular arbuscular mycorrhizas (VAM) and 25 kg P_2O_5+PSB+VAM) and cutting (no cutting, one and 2 cuttings) management practices. Application of 50 kg P_2O_5/ha being at par with application of PSB+VAM+25 kg P_2O_5/ha recorded the maximum branches per plant, seeds per pod, 1000-seed weight, seed yield and nodules per plant.

Farahani *et al.* (2007) while studying the effects of *Glomus hoi* fungi, different levels of phosphorus and drought stress on certain physiological characteristics of coriander (*Coriandrum sativum*). Observed that drought stress had significant effect on water use efficiency, relative water content and proline accumulation rate (alpha =1%). Comparison of means showed that the highest water use efficiencies of 0.395 kg/m^3 and 0.4 kg/m^3 were achieved upon treatment with mycorrhizal application and application of 70 kg P/ha, respectively.

Nandal *et al.* (2007) reported that the experiment consisted of four levels of nitrogen (20, 40, 60 and 80 Kg N/ha) and three levels of phosphorus (35, 50 and 65 Kg P/ha) applied as basal dose and top dressing as per treatment. Application of 80 Kg N/ha and 65 Kg P/ha significantly increased the plant height and number of primary branches per plant. The results indicated that application of 60 Kg N+65 Kg P/ha produced highest test weight (10.4 g) as well as seed yield (20.4 q/ha).

Sammauria and Yadav (2008) reported that the significant improvements were recorded in branches per plant, pods per plant, test weight, seed, straw and biological yield of fenugreek up to the application of 40 kg P_2O_5/ha, whereas seeds per pod increased only up to 20 kg P_2O_5/ha.

Kumawat and Yadav (2009) reported that the application of phosphorus increased the yield attributing parameters, yield, root nodules and uptake of N, P, K, Ca and Na. The increasing level of EC_{IW} decreased the plant height, total number of nodules per plant, seed index, seed and straw yield and nutrient uptake by seed and straw.

Tripathi *et al.* (2009) reported the effect of nutrient levels (% recommended NPK fertilization) on growth, yield, quality of coriander (*Coriandrum sativum* L). The application of 100% recommended dose of fertilizer (RDF) (60:17.6:16.6:30 kg N:P:K:S/ha) registered significantly higher yield attributes, water use efficiency, production efficiency, N:P:K and S uptake and 20.65% and 12.04% increased in seed yield over 50% and 75% RDF, respectively.

Valadabadi *et al.* (2009) reported the effects of P_2O_5 fertilizer according to physiological growth indices of coriander with 4 replications with 0, 16 and 32 kg/ha P_2O_5 fertilizer (triple super phosphate). The results of seven sample stages showed that applications of and 70 kg/ha phosphorus without drought stress conditions increased dry matter, leaf area index, relative growth rate, net assimilation rate and crop growth rate.

Nandal *et al.* (2010) reported that the response of spacing, phosphorus levels and cutting of leaves on growth and yield of coriander cv. Hisar Anand three levels of phosphorus (25, 50 and 75 kg P_2O_5/ha), two spacing (20x20 and 40x10 cm) and three cutting of leaves (C_0-Control, C_1-One cutting at 30 days, C_2-two cutting at 30 and 50 days after sowing). Significantly the higher green leaf yield was recorded in the treatment combination of highest levels of phosphorus (75 kg) + spacing (20x20 cm) and two cuttings of green leaves treatment. Minimum seed yield was recorded in 25 kg P_2O_5/ha + 20x20 cm spacing with two cuttings of green leaves treatment combination

Mehta *et al.* (2010) reported that the application of 20 kg N and 40 kg P_2O_5 ha^{-1} resulted in more number of nodules per plant and higher dry weight per plant over 10 kg N and 20 kg P_2O_5 ha^{-1}, at 40 and 60 days after sowing (DAS), respectively. Similarly, nodules per plant and their dry weight also significantly increased with increasing level of nitrogen and phosphorus.

Sammauria and Yadav (2010) reported that the effect of phosphorus and zinc applied to fenugreek, on the performance of fenugreek (*Trigonella foenum-graecum*)-pearlmillet (*Pennisetum glaucum*) cropping system. Application of 17.5 kg P/ha and 5.0 kg Zn/ha resulted in 24.7 and 14.7% higher seed yield of fenugreek. Application of 26.2 kg P/ha and 7.5 kg Zn/ha to fenugreek significantly increased the content and uptake of P and Zn in fenugreek and pearl millet. Combined application of 26.2 kg P/ha+7.5 kg Zn/ha resulted in the highest yields of both the crops.

2.2 Effect of Growth Regulators

2.2.1 Effect of GA_3

Jain *et al.* (1988) in an experiment treated the seeds of *Trigonella foenum-graecum* and *Trigonella corniculata* with different concentrations of GA_3 and IAA and seedlings of 2 and 8 weeks old were studied for their steroidal sapogenin content. They found that there was increase in the level of steroidal sapogenin (diosgenin + tigogenin) in both the treatments with a maximum enhancement at 100 ppm GA_3 in both the species.

Shahine *et al.* (1992) reported that there was increase in P content of fenugreek seed cv. Baladi with 1 or 10 ppm GA_3 foliar spray.

Badge *et al.* (1993) reported that the foliar spray of 25 ppm GA_3 gave the highest seed yield of fenugreek cv. Kasuri.

Bhat and Singh (1997) studied the effect of different levels of phosphorus, GA_3 and picking on growth and seed yield attributing parameters of okra cultivar Pusa Sawani and that application of phosphorus and seed treatment with GA_3 for 12 hrs were not encouraging the growth but yield is significantly high.

Moraes, D. M. de Lopes, N. F (1998) studied the effects of growth regulators and their interactions with germination, vigour and dormancy breaking were evaluated in Coriander cv. Palmeira Nacional seeds and found that 100% seed germination. And found that seeds treated with GA_3 reached total emergence, the concentration of 50 mg/kg was enough to induce 100% emergence. The seeds treated with CEPA at the maximum rate (200 mg/kg) reached 49% seed germination. Seeds treated with GA_3 + CEPA at 200 mg/kg attained 87% emergence.

Bhople *et al.* (1999) observed that the foliar application of triacontanol (2.5, 5.0, 7.5 and 10.0 ppm), NAA (25, 50 and 75 ppm) and GA_3 (25, 50 and 75 ppm) significantly increased the yield attributes and seed yield of onion but the highest values were obtained with 75 ppm GA_3.

EL-Keltwai *et al.* (2000) assessed different methods of GA_3 application and found that two supplemental sprays in addition to the initial seed soaking increased vegetative growth and yield of cumin compared to soaking alone and control.

Kumar *et al.* (2000) reported that foliar application of GA_3 (50 and 100 ppm), IBA (5 and 10 ppm) and NAA (100 and 200 ppm) significantly increased curd circumference and curd yield but GA_3 at both levels produced significantly higher plant height, curd circumference and curd yield in cauliflower cv. Pant Subhra.

Balraj *et al.* (2002) conducted a field experiment with GA_3, NAA and 2, 4-D each at two levels of concentration was sprayed thrice on chilli and it was observed that 100 ppm GA_3 recorded significantly highest plant height and number of branches at all stages of growth followed by 50 ppm GA_3.

Nair *et al.* (2002) reported that the foliar application of GA_3 100 ppm in gerbera from January to May at monthly interval produced significantly higher plant height, number of leaves, number of flower/pot, length of flower stalk as well as flower size over control.

Verma (2002) observed that 50 ppm GA_3 through soaking + spraying resulted in increased plant growth and yield parameters of coriander.

Bialecka, B. Kepczynski, J (2003) observed that BA at 10^{-5} *M*, GA_3 at $3x10^{-4}$ *M* or GA_{4+7} at $3x10^{-5}$ *M* partially or largely reversed the inhibition of *Amaranthus caudatus* seed germination due to JA-Me (methyl jasmonate). BA or GA_3 did not affect ethylene production and ACC oxidase activity *in vivo* in the presence of JA-Me before radicle protrusion. However, both increased ethylene production after 72 h of incubation, when the reversal of the JA-Me inhibition of seed germination was observed. AVG at $3x10^{-4}$ *M* decreased ethylene production when it was applied simultaneously with BA and JA-Me or GA_3 and JA-Me, but it had no effect on seed germination.

Purbey and Sen (2005) observed that the effect of foliar application of bioregulators at 20 ppm NAA, significantly increased number of pods per plant (32.65), pod length (13.48 cm), number of seeds per pod (17.16), shelling percentage (73.28), seed and straw yields (1.76 and 4.70 tonnes/ha).

Meena *et al.* (2006) reported the effect of sowing date, nitrogen and plant growth regulators on the growth and yield of coriander (*Coriandrum sativum* cv. RCr-41). It was observed that the sowing on 15 October resulted in crops with significantly highest plant height, number and weight of green leaves per plant, number of branches and number of nodes on the main shoot per plant, the highest number of umbels per plant, umbellets per umbel, seeds per umbel, test weight, biological yield and stover yield and thus contributed towards the highest seed yield of 12.57 q/ha. Foliar spray of NAA at 30 days after sowing resulted in significant higher growth and seed yield, which was at par with GA spray at 30 days after sowing.

Meena *et al.* (2006) reported the effect of sowing dates, nitrogen and plant growth regulators on quality of coriander (*Coriandrum sativum* L.). Early (15th October) sown coriander crop recorded significantly higher chlorophyll and carotenoids content in leaves and essential oil in seeds over 15th November sown crop. Foliar spray of 25 ppm NAA or 50 ppm GA_3 at 30 DAS exhibited significantly higher chlorophyll and carotenoids content in leaves and essential oil content in seeds over other treatments.

Shah, S. H. Samiullah (2006) conducted a study with foliar spray of 0 (deionized water), 10^{-6}, 10^{-5} and 10^{-4} M each of gibberellic acid (GA_3) or Kinetin (KIN) at 40 days after sowing (vegetative stage) on growth and yield of black cumin (*Nigella sativa*). GA_3 application at 10^{-5} M concentration was more effective than KIN in promoting shoot length, plant dry weight, leaf number, leaf area and branch number observed 70 days after sowing (DAS). Application of 10^{-5} M GA_3 resulted in more capsule number, seed yield and seed yield.

Shah *et al.* (2006) studied the effects of hormone treatment on black cumin (*Nigella sativa*), sprayed with either deionized water (control) or 10^{-5} M GA_3 at 40 (vegetative stage) or 60 (flowering stage) days after sowing (DAS). Capsule number/plant, seeds/capsule, 1000-seed weight, seed yield (q/ha), harvest index and seed yield merit (SYM) were analysed at harvest. It was noted that growth, NPK accumulation and seed yield were maximal when spraying of GA_3 was carried out at 40 DAS.

Paramanik *et al.* (2007) observed that application of GA at 10^{-5} M concentration sprayed 40DAS was found to be more effective in promoting root, shoot length, plant dry weight, leaf number, leaf area and branch number in black cumin they also reported that application of 10^{-5} M GA, resulted in more capsule number, seed yield and seed yield merit, which was found increased by 43.33, 43.85 and 53.62%, respectively.

Pariari *et al.* (2007) reported that the application of gibberellic acid (GA_3), ethrel (ethephon) and NAA at 50, 75 and 100 ppm each. The results showed that highest number of primary and secondary branches were obtained with 100 ppm ethrel application. Foliar application of 50 ppm GA_3 obtaining maximum number of pods per plant (59.06), pod length (11.45 cm), number of seeds per pod (12.80) and seed yield/ha (12.50 q).

Ipek *et al.* (2008) observed that the effect of seed age (fresh, 3, 6, 9, 12, 15, 18, 21 and 24 months) and GA_3 (distilled water, 100, 200 and 400 ppm) application on germination of cumin and fenugreek seeds. The seed germination rate varied between

95.5 and 100 percent in fenugreek and 18.5-79.0% in cumin. GA_3 enhanced the germination rate of aged cumin seeds but did not significantly affect fenugreek seeds.

Piyush Verma Sen (2008) observed that the effect of GA_3 50 ppm applied through pre-plant soaking+spraying 20 DAS recorded maximum plant height (23.85 cm) and number of green leaves per plant (22.03), while fresh weight of leaves per plant (5.58 g) and carotenoid content (1.075 micro g/g) were recorded with NAA 20 ppm applied through pre-plant soaking+spraying 20 DAS mode. Higher concentration of NAA (50 ppm) when applied through pre-plant soaking+spraying 20 DAS mode resulted in maximum total chlorophyll content (16.43 micro g/g). GA_3 at 50 ppm applied through pre-plant soaking+spraying 20 DAS significantly improve the vegetative growth of coriander herb while NAA at 50 ppm improved the quality of the coriander herb.

Vasudevan (2008) observed that the influence GA_3 (100 ppm) followed by boron (0.1%) produced more number of productive branches (6.68 & 6.48 respectively) and seed yield (8.53 & 8.06 q/ha respectively).

Bialecka and B. Kepczynski (2009) studied that effects of different doses of ethephon and gibberellin on germination and alpha - and beta -amylase activity in *Amaranthus caudatus* seeds exposed to different levels of salt stress. Both ethephon and GA_3 (0.01, 0.1, 0.3 mM) effectively counteracted inhibition of seed germination under salinity. The stimulatory effect of ethephon appeared earlier, and the seeds were more sensitive to ethephon than to GA_3. Ethephon and GA_3 increased alpha - but not beta -amylase activity under salt stress during the first 14 h of incubation.

Ritu Gupta (2009) find out the effects of growth regulators viz., IAA, IBA, NAA and GA_3 on seed germination and seedling growth of fenugreek has been studied. Treatment with various growth regulators improved seed germination and seedling growth as compared to control. IAA improved rooting while GA_3 promoted shooting.

2.2.2 Effect of NAA

Mehra and Kamal (1995) reported that the foliar spray of NAA 10 ppm increased the seed yield and seed diosgenin content in seed of fenugreek cv. NLM (Prabha) compared with water treated plants.

Bhople *et al.* (1998) while studying effect of foliar application of GA_3 (50, 75, 100 ppm), triacontanol (2, 5, 7.5 and 10 ppm) and NAA (50, 75 and 100 ppm) on radish cv. Pusa Chetki found that the highest values were obtained with 100 ppm NAA, gave significantly increased seed yield per plot, 1000 seed weight and seed yield q/ha. as compared to control

Alagukannan and Vijay Kumar (1999) in a field trial of fenugreek cv. Co-1 observed that foliar application of NAA at 20 ppm gave the significantly higher number of pods per plant, double pods per plant, pod length, seed per pod, test weight, harvest index and seed yield q/ha while NAA at 15 ppm gave the significantly higher seed protein content.

Medhi (2000) reported the highest number of pods per plant, pod length, grain per pod, pod yield and chlorophyll content in french bean with foliar application of NAA (15 ppm).

Meena and Malhotra (2006) reported significant variation in plant height, number of branches, number of green leaves and yield of green leaves per plant with different sowing dates and growth regulators in coriander. The 15th October sown crop was found best for green leaf yield of coriander. Foliar application of 25 ppm NAA at 30 days after sowing (DAS) gave maximum number of green leaves per plant and green leaf yield per plant which was significantly higher over control.

Piyush Verma Sen (2006) observed that the nine levels of plant growth regulators (indole acetic acid, naphthalene acetic acid and gibberellic acid, each at 10, 25 and 50 ppm concentration) and three modes of application (soaking of seeds, spraying 20 days after sowing and soaking + spraying) was conducted to study their effect on growth and yield of coriander (*C. sativum* cv. RCr-435). The results revealed that application of gibberellic acid 50 ppm by soaking + spraying resulted in maximum number of nodes on main shoot (7.60), number of branches $plant^{-1}$ (9.51), number of umbels $plant^{-1}$ (25.36), biological yield (1.274 q ha^{-1}) and seed yield (0.432 q ha^{-1}).

Bairwa and Kaushik (2007) studied the effect of cultivars (Rmt-1 and Rmt-303), fertilizer levels (0, 10 kg N+20 kg P_2O_5, 20 kg N+40 kg P_2O_5 and 30 kg N+60 kg P_2O_5/ha) and growth regulators (water spray (control), ethephon at 100 ppm and NAA at 20 ppm) on fenugreek yield and yield attributes. Rmt-303 gave significantly higher number of pods per plant, seeds per pod, test weight, grain and straw yields compared to Rmt-1. Application of 30 kg N+60 kg P_2O_5/ha resulted in significantly more grain and straw yields, number of pods per plant, seeds per pod and test weight. Significantly higher grain and straw yields, number of pods per plant, seeds per pod and test weight were recorded when NAA (20 ppm) spray was given at the preflowering stage compared with ethephon (100 ppm) during both years.

Bhalerao *et al.* (2007) studied the effects of foliar sprays (at 25, 50 and 75 days after sowing) of bioenzymes and plant growth regulators on the growth and seed yield of methi (*T. foenum-graecum* cv. Pusa Early Bunching). There were 14 treatments comprising NAA at 200 ppm (T1), Biozyme at 2 ml/l (T2), Fulltoss at 2 ml/l (T3), Humicil at 2 ml/l (T4), Multizyme at 2 ml/l (T5), Novazyme at 2 ml/l (T6), Novacharge at 2 ml/l (T7), Plantozyme at 2 ml/l (T8), Supercropenzyme at 2 ml/l (T9), N-triacontanol at 2 ml/l (T10), Supercropecharge at 2 ml/l (T11), Shaktizyme at 2 ml/l (T12), water spray (T13) and control (T14). It was observed that T6 recorded the highest seed yield (21.91 q/ha), followed by T3 (19.35 q/ha) and T2 (19.21 q/ha). T3 recorded the earliest flowering and pod setting.

Purbey and Sen (2007) found that the foliar application of bioregulators viz. GA_3, NAA and Brassinosteriod had significant effect on yield, nutrient content and uptake by the crop. However, 20 ppm NAA spray produced mean maximum of 17.60 and 47.05 q/ha seed and straw yield, respectively. N and P content and uptake by the fenugreek crop were the highest under 20 ppm NAA which was closely followed by 10 ppm NAA treatment.

Dutta et al. (2008) studied the response of fenugreek (*T. foenum-graecum*) to P levels (0, 13.1 and 26.2 kg/ha) and growth regulators (NAA at 20 ppm, triacontanol at 4 ppm, IBA at 40 ppm and control). Foliar spray of NAA at 20 ppm proved significantly superior over the control, triacontanol and IBA in enhancing productivity.

Sarada *et al.* (2008) reported the effect of plant growth regulators and their time of application on growth and yield of coriander. Triacontanol @1.0 ml/lt recorded maximum plant height, more number of branches and more number of umbellets per umbel. NAA @10 ppm recorded more number of umbels per plant and increased crop duration. Maximum seed yield was recorded with NAA @10 ppm followed by Triacontanol @1.0 ml/lt.

Singh (2010) find out the effect of bio-regulators *viz.*, *Triacontanol* @ 0.5 ml/l of water, NAA @ 50 ppm, GA @ 50 ppm and water sprayed on growth and yield of fenugreek (*Trigonella foenum-graecum* L.) variety Rajendra Kanti. Spraying of Triacontanol @ 0.5 ml/liter water, NAA @ 50 ppm and GA @ 50 ppm gave significant effect on yield and yield attributing character as compare to water sprayed. Maximum plant height, number of branches per plant, number of pods per plant, length of pod, number of grains per pod and yield was recorded by spraying Triacontanol @ 0.5 ml/l.

2.2.3 Effect of Ethrel

Khateeb, (1994); Alhadi *et al.* 1998 and Keltawi *et al.* 2000 observed that the plant growth regulators like GA_3 and Ethrel react favorably with different seed spices when applied judiciously.

Alagukannan and Vijaykumar (1999) found that the foliar application of growth substance viz. Ethrel, MH, 2, 4,-D and NAA has significantly increased the number of pods per plant, seeds per pod, test weight, harvest index and yield of fenugreek.

Sahu *et al.* (2002) reported that the GA_3 and Ethrel increased significantly the growth, yield and yield attributing characters of fenugreek, such as pods per plant, pod length, seed per pod, seed yield per plant, test weight, yield per ha. and harvest index.

Kuldeep Kumar *et al.* (2007) evaluated the effect of GA_3 and Ethrel on carrot seed crop cv. Hisar Gairic. Application of GA_3 2 ppm (Dip)+50 ppm (Foliar spray) and GA_3 100 ppm alone as foliar spray 40 days after steckling planting significantly improved the plant height, number of branches, umbels and seed yield per plant and per hectare in comparison with control.

Panda *et al.* (2007) reported the highest plant height, number of primary branches per plant, and number of secondary branches per plant with GA_3 10 ppm while yield attributing characters, corbohydrates and protein content increased with increasing levels of GA_3 and decreased with increasing levels of ethrel. GA_3 at 100 ppm recorded the highest number of umbels per plant, number of seeds per umbel, test weight, seed yield per plant and seed yield per hectare.

Pariari *et al.* (2007) observed that the response of fenugreek showed that highest number of primary and secondary branches were obtained with 100 ppm ethrel application. Foliar application of 50 ppm GA_3 showed the best result for obtaining maximum number of pods per plant (59.06), pod length (11.45 cm), number of seeds per pod (12.80) and seed yield/ha (12.50 q). Foliar application of 50 ppm GA_3 at 30 and 45 days after sowing in addition to the normal fertilizer schedule increased the production and productivity of fenugreek in the Gangetic alluvial plains of West Bengal.

Kumar *et al.* (2008) observed that the effect of different concentration of Ethrel (50 ppm, 75 ppm, 100 ppm and 125 ppm) along with ace (a commercial bioregulator @ 0.5 ml/lit). Among all the treatments, Ethrel @ 75 ppm proved to be most effective in promoting growth and gave highest seed yield (6.03 q/ha) followed by Ethrel @ 100 ppm (5.59 q/ha) which was statistically at par.

Menaka *et al.* (2008) The freshly harvested seeds of amaranthus cv. Co 5 will not germinate under normal condition due to dormancy. To improve the germination, seeds were treated with different chemicals, i.e. GA_3, IAA, ethrel, thiourea and KNO_3, at different concentrations and soaking durations. Among them, soaking the seeds in ethrel at 200 ppm for 12 h excelled other treatments in increasing the germination significantly from 28 to 95%.

Mir *et al.* (2008) The mustard plants (*Brassica juncea* L. Czern and Coss) cv. 'Alankar', grown on a soil treated with 40, 60 and 80 kg N ha^{-1}, were sprayed with 0.02% ethrel (2-chloro-ethyl phosphonic acid) at flowering stage [60 days after sowing] to observe the changes in leaf area index, net photosynthetic rate, nitrate reductase activity and plant dry biomass on 80, 100 and 120 DAS. At harvest, the pod number $plant^{-1}$, 1000-seed weight and seed yield were also recorded. Ethrel (0.02%)+80 kg N ha^{-1} treatment enhanced leaf area index, net photosynthetic rate, nitrate reductase activity, plant biomass by 75.5, 56.4, 72.1 and 39.1%, respectively, while pod number $plant^{-1}$, 1000-seed weight and seed yield were enhanced by 27.2, 5.6 and 71.9%, respectively.

Lone *et al.* (2010) found that the plants of mustard (*Brassica juncea* L. Czern and Coss; cultivar Alankar) were treated with 200 micro L/L ethrel (2-chloro ethyl phosphonic acid) at flowering stage (60 d after sowing) along with basal application of nitrogen 40, 60, and 80 kg N ha^{-1}. Effect of ethrel and nitrogen on leaf area index (LAI), net photosynthetic rate (P_N), nitrate reductase (NR) activity and plant dry mass were recorded at 80 and 100 d after sowing. At harvest pods $plant^{-1}$, 1000 seed mass and seed yield were recorded. Ethrel 200 micro L/L x 80 kg N ha^{-1} treatment enhanced all the characteristics studied during the experiment.

CHAPTER III

MATERIALS AND METHODS

The field experiment entitled “Effect of phosphorus and plant growth regulators on growth, yield and quality of fenugreek” was conducted during the *rabi* season of 2010-2011. Details of the methods and techniques followed in the experiment are given below. The experimental materials and criteria used for treatment evaluation during the course of investigation are being presented in this chapter.

3.1 Experimental site

The experiment was laid out at the “Model orchard” College of Horticulture, APHU Hyderabad (A.P.) during “*rabi*” season of 2010-11. This region falls under Agro climatic zone no.VI of the state.

3.2 Climate and weather condition

The experimental site is laid out in model orchard at Rajendranagar, Hyderabad comes under sub-tropical zone and is situated at latitude of $17^{0}19^{”}$ N and longitude of $79^{0}23^{”}$ E, the altitude of the place is 542.3 m above mean sea level. The mean annual precipitation is 852 mm which was received almost from South-West Monsoon during June to October. The mean annual minimum and maximum temperatures are 20.2^{o}C and 32.6^{o}C respectively. The humidity ranges from 44.5 % in summer and 79.4 % in rainy season. Hyderabad thus has hot dry summer and moderate cold winter.

The meteorological data in respect of rainfall, humidity, maximum and minimum temperature was collected from Agricultural Research Institute, Rajendranagar for the period of October, 2010 to February, 2011 and furnished in Appendix-1.

3.3 Soil characteristics of the Experimental Site

The soil of an experimental plot was uniform in texture and was levelled. In order to understand the physical and chemical properties of the soil, a representative soil samples were collected from 15-20 different locations after scrapping the surface litter, a uniform core or a thin slice of soil from the surface to a plough depth (15-22 cm) (Seetharaman *et al*., 1994). The physical and chemical analysis of the soil of experimental plots was done before commencement of the experiment and details of the soil analysis are furnished below.

Chemical properties of the experimental soil

Chemical ingredient	**Analysis of quantity/ percentage**	**Method adopted**
Total 'N' kg ha^{-1}	537.6 kg ha^{-1}	Kjeldal's digestion method described by Chapman and Pratt (1961)
Available 'N' kg ha^{-1}	192.0 kg ha^{-1}	Alkaline permanganate method as described by Subbaiah and Asija (1956)
Available 'P' kg ha^{-1}	72.5 kg ha^{-1}	Olsen's method as described by Jackson (1967)
Available 'K' kg ha^{-1}	245.0 kg ha^{-1}	Neutral normal ammonium acetate method as described by Jackson (1967)
Organic Carbon (C) content	0.57 %	Walkley and Black wet oxidation method (Jackson,1967)

Physical properties of the experimental site

Ingredient	Quantity (%)	Method adopted
Sand	71.9	International pipette method (Piper-1966)
Silt	7.8	International pipette method (Piper-1966)
Clay	18.5	International pipette method (Piper-1966)

3.4 TECHNICAL PROGRAMME OF WORK

Experimental Details

1. Location : College of Horticulture, Rajendranagar, Hyderabad
2. Crop : Fenugreek
3. Variety : LS-1
4. Season : Rabi season 2010-11
5. Design : Randomized Block Design
6. Number of treatments : 18
7. Number of Replications : 03
8. Total Number of plots : 54
9. Row to Row distance : 30 cm
10. Plant to plant distance : 10 cm
11. Replication distance 100 cm
12. Experimental area 14.5 m X 24 m = 348 m^2
13. Gross plot area 3 m X 2 m = 6 m^2

14. Net plot area 2.40 m x 1.80 m = 4.32 m^2

15. Date of sowing 17^{th} December, 2010

16. Date of Harvesting 14^{th} March, 2011

3.5 Experimental Materials

The experimental material comprised phosphorus in combination with plant growth regulators. The treatment combinations were as follows:

T_1 = 50 kg N : 20 kg P_2O_5 : 20 kg K_2O

T_2 = 50 kg N : 40 kg P_2O_5 : 20 kg K_2O

T_3 = 50 kg N : 60 kg P_2O_5 : 20 kg K_2O

T_4 = 20 kg P_2O_5 + Control (water spray)

T_5 = 40 kg P_2O_5 + Control (water spray)

T_6 = 60 kg P_2O_5 + Control (water spray)

T_7 = NAA at 20 ppm

T_8 = 20 kg P_2O_5 + NAA at 20 ppm

T_9 = 40 kg P_2O_5 + NAA at 20 ppm

T_{10} = 60 kg P_2O_5 + NAA at 20 ppm

T_{11} = GA_3 at 50 ppm

T_{12} = 20 kg P_2O_5 + GA_3 at 50 ppm

T_{13} = 40 kg P_2O_5 + GA_3 at 50 ppm

T_{14} = 60 kg P_2O_5 + GA_3 at 50 ppm

T_{15} = Ethrel at 75 ppm

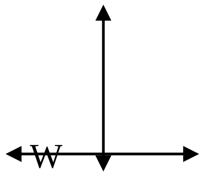
T_{16} = 20 kg P_2O_5 + Ethrel at 75 ppm

T_{17} = 40 kg P_2O_5 + Ethrel at 75 ppm

T_{18} = 60 kg P_2O_5 + Ethrel at 75 ppm

3.5.1 Experimental design and layout

The description of design and layout is as follows:



RI		RII		RIII
T_2		T_6		T_5
T_4		T_{10}		T_3
T_{13}	I	T_8	I	T_{10}
T_1	R	T_3	R	T_{12}
T_{11}	R	T_7	R	T_2
T_7	I	T_{11}	I	T_4
T_6	G	T_{13}	G	T_9
T_8	A	T_4	A	T_{11}
T_3	T	T_1	T	T_6
T_5	I	T_{12}	I	T_8
T_{12}	O	T_9	O	T_1
T_{10}	N	T_2	N	T_{13}
T_9		T_5		T_7

T_{15}	C	T_{17}	C	T_{16}
T_{16}	H	T_{14}	H	T_{18}
T_{14}	A	T_{16}	A	T_{17}
T_{18}	N	T_{15}	N	T_{14}
T_{17}	N	T_{18}	N	T_{15}
	E		E	
	L		L	

3.6 Cultural Operations

3.6.1 Field preparation

The field was properly ploughed by disc plough and then pulverized by disc harrow. Then after, field was leveled properly with heavy wooden planker by tractor and then plots were prepared according to the layout plan.

3.6.2 Application of manures and fertilizers

A basal dose of well rotten farmyard manure at the rate of 30 tones per hectare was incorporated in the soil before one month of sowing. In addition to this, an uniform dose of 30 kg N/ha through Urea, 25 kg K_2O/ha through Murate of potash and the calculated quantities of the phosphorus through Dia ammonium phosphate.

3.6.3 Variety used

The variety used in this experiment was LS-1. This variety is suitable for Andhra Pradesh region, tolerant to root rot and powdery mildew, caterpillars and aphids with good quality and yield.

3.6.4 Seed and sowing

The seeds of Fenugreek cv. LS-1 were procured from LAM Farm, Guntur. The pure, healthy, disease and insect free, vigorous and good quality seeds were used for sowing. The seeds were treated with Trichoderma @ 1-2 g per kg seed and then sown at a depth of 5 cm in plant spacing at 30 cm x 10 cm with seed rate 20 kg per ha.

3.6.5 Weeding and thinning

Thinning was done at 25 DAS to maintain plant to plant distance of 10 cm. Then hand weeding was done to check the weed in the crop at 20, 40 and 70 days after sowing.

3.6.6 Plant protection measures

The crop was sprayed with monocrotophos 35 EC at flowering and pod formation stage to prevent the aphid infestation. Soil was drenched with mancozeb @ 0.2% and carbendazim @ 0.1% /liter water, thrice at an interval of 25, 45 and 60 DAS to prevent the root rot infection, and crop was sprayed with wettable sulphur (25%) at pod formation stage to prevent the powdery mildew.

3.6.7 Irrigation

For the establishment of the crop, first light irrigation was done immediately after the sowing then subsequent irrigations were done at different intervals, as per the crop requirement.

Irrigation	**Date**
First	17th December
Second	30th December
Third	14th January
Fourth	23rd January
Fifth	10th February

3.6.8 Harvesting

The crop was harvested at 87 DAS i.e. on 14th March 2011. The fenugreek plants were harvested separately for each treatment.

3.6.9 Threshing and winnowing

After sun drying, the threshing of the individual plot was done with the help of wooden sticks and winnowed traditionally to separate seed and straw. Seeds were weighed and plot wise samples were taken. Seed and straw were separated for further analysis.

3.6.10 Observations taken during the course of investigation

A. Growth Attributes

i) Plant height (cm) at 30, 60 DAS and at harvest
ii) Number of branches per plant at 30, 60 DAS and at harvest

B. Yield and Yield Attributes

i) Number of pods per plant
ii) Number of seeds per pod
iii) Days to 50% flowering
iv) 100-seed weight (g)
v) Seed yield (q/ha)
vi) Straw yield (q/ha)
vii) Harvest index (%)

C. Mineral composition

i) N, P, K content of seed (%)
ii) Protein content of seed (%)
iii) Chlorophyll content in leaves (mg/g)

3.6.11 Observation and procedure

Observations were recorded on the following growth, yield and quality attributing characters of fenugreek.

3.6.12 Sampling technique

Five plants were randomly selected from each plot and tagged for recording observation on various characters.

3.6.13 Growth parameters

1. Plant height (cm)

The plant height was measured from the ground level to the tip of the last leaf. The average was worked out and expressed as plant height in cm.

2. Number of branches per plant

The branches from five randomly selected plants from each plot were counted at 30, 60 DAS and at harvest. The average was computed and expressed as number of branches per plant.

3. Fresh and dry matter accumulation (g/m^2)

Five plant randomly selected plants were removed from each experimental unit at 30, 60 DAS and at harvest. The samples were first weighed and average was worked out and expressed as gram per plant and gram per square metre, after taken the fresh weight the samples were dried in air and then in oven at 70^{0}C for 24 hours till constant weight. The dry matter was weighed and average was worked out and expressed as g/plant and gram per square metre.

3.6.14 Yield and yield parameters

1. Number of pods per plant

The pods of five randomly selected plants from each plot at the time of harvesting were counted and average number of pods per plant was recorded.

2. Number of seeds per pod

Seeds of 25 selected pods from sampled plants of each plot were counted and their average was recorded as number of seeds per pod.

3. Test weight (g)

One thousand seeds were counted in samples taken from the finally winnowed and cleaned produce of each plot after weighing. These seeds were weighed on electronic balance and the weight was recorded as test weight (g).

4. Seed yield (q/ha)

After threshing and winnowing, clean grains obtained from individual plots were weighed and the weight was recorded in kg per plot. This was then converted in to q/ha.

5. Straw yield (q/ha)

Straw yield was calculated by subtracting the seed yield (q/ha) from the biological yield (q/ha).

6. Days to Fifty per cent flowering

Number of days was counted from the date of sowing to the date when 50 per cent plants from three randomly selected spots of 0.5m row length in each plot have appearance of flowers. The average was worked out and expressed as number of days to 50 percent flowering.

7. Harvest index (%)

The harvest index was calculated from the economic yield (seed yield) and total biological yield and expressed as percentage

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q/ha)}}{\text{Biological yield (q/ha)}} \times 100$$

8. Biological yield (q/ha)

The harvested and sun dried crop of each plot was weighed and the weight was recorded in kg/plot and then converted to quintal per hectare.

3.6.15 Quality parameters

1. N, P, K content of seed

a) Nitrogen content:

Nitrogen content of the seed was determined by digestion 0.1 g plant sample with H_2SO_4 for removing black colour. Estimation of nitrogen was done by colorimetric method using Nessler's reagent to develop colour (Snell and Snell, 1939). Nitrogen was calculated and expressed in percentage.

b) Phosphorus and Potassium content:

Phosphorus and Potassium content were estimated by wet digesting plant samples with tri-acid mixture of HNO_3:H_2SO_4:$HClO_4$ and estimated for their constituent as follows:

Phosphorus: Phosphorus content was determined by Vanadomolybdo phosphate yellow colour method (Jackson, 1967).

Potassium: Potassium was estimated by Flame photometric method (Jackson, 1967).

2. Protein content

The Protein content of the seed was calculated by multiplying percent nitrogen content in seed with the factor 6.25 (A.O.A.C., 1960).

3. Chlorophyll content in leaves

The chlorophyll was estimated from representative samples. Fully expanded leaves, at the time of flowering and pod filling stage by soaking of leaves in 5 ml dimethyl sulphoxide. The amount of chlorophyll present in the extract was calculated and expressed as mg per gram of leaf by the following formulae (Strain and Svec, 1966).

$$\text{Chlorophyll "a"} = \frac{12.25\,(A\,663) - 2.69\,(A\,645)}{a \times 1000 \times w} \times v$$

$$\text{Chlorophyll "b"} = \frac{22.9\,(A\,645) - 4.68\,(A\,663)}{a \times 1000 \times w} \times v$$

3.6.16 Economics of treatments

The economics of different treatments were worked out in terms of net return per hectare and cost of the treatment. The benefit : cost (B : C) ratio was also calculated treatment wise to ascertain economic viability of the treatment. Cost of production and net profit were calculated on the basis of prevailing prices of product and inputs.

3.7 Statistical analysis

The data recorded on various characters for each treatment were subjected to "Analysis of Variance" as recommended by Panse and Sukhatme (1985).

The significant difference between different treatments were evaluated by using critical differences (CD) which were calculated with the help of the standard error of mean (SEm ±) by using the formulae given below

(i) Standard error of mean (SEm ±)

(a) SEm ± for P = $\sqrt{\dfrac{\text{EMS}}{\text{No. of replications X Levels of G}}}$

(b) SEm ± for G $= \sqrt{\dfrac{EMS}{\text{No. of replications X Levels of P}}}$

(c) SEm ± for PG $= \sqrt{\dfrac{EMS}{\text{No. of replications}}}$

(ii) Critical difference (CD)

(a) CD for P = SEm ± (p) x$\sqrt{2}$ x t edp at 5%

(b) CD for G = SEm± (g) x $\sqrt{2}$ x t edg at 5%

(c) CD for PG = SEm± (pg) x$\sqrt{2}$ t edp at 5%

CHAPTER IV

RESULTS

The results of the field experiment, entitled “Effect of phosphorus and plant growth regulators on growth, yield and quality of Fenugreek (*Trigonella foenum graecum* L.)” conducted during the *Rabi* season 2010-11, are described in this chapter. The results for treatment effects and interactions are presented.

4.1 GROWTH PARAMETERS

Data on various growth characters of fenugreek crop as influenced by the treatments are presented.

4.1.1 Effect of phosphorus and plant growth regulators on plant height (cm)

Perusal of data (Table 4.1 and F. 4.1) revealed that phosphorus had significant effect on plant height 30, 60 DAS and at harvest with mean maximum and minimum plant height was 12.10 cm and 10.86 cm at 30 DAS, 31.82 cm, 30.04 cm at 60 DAS and 50.13 cm and 45.63 cm at harvest stage with the application of 60 kg P_2O_5 /ha and at 20 kg P_2O_5 /ha respectively. However the treatment RDF has recorded maximum plant height of 12.40 cm.

It was evident from the data (Table 4.1 and fig. 4.1) that plant growth regulator had significant effect on plant height at 30, 60 DAS and at harvest in the order of GA_3>NAA>control Ethrel. The maximum plant height was found with GA_3 50 ppm 10.02 cm and minimum with Ethrel 75 ppm 9.82 cm, at 30 DAS and was non significant, mean maximum plant height of 35.02 cm at 60 DAS and 51.96 cm at harvest was recorded with the application of GA_3 50 ppm. And was significantly superior to the treatments including plant growth regulators.

Among the different treatment combinations, plant growth regulators and phosphorus application of at 60 kg phosphorus with GA_3 50ppm had significant effect on plant height at 30, 60 DAS and at harvest with a mean maximum 12.00 cm, 37.21 cm and

56.64 cm, while minimum observed was 10.58 cm, 26.58 cm and 40.68 cm with application of 20 kg phosphorus with Ethrel 75 ppm at 30, 60 DAS and at harvest respectively.

4.1.2 Effect of phosphorus and plant growth regulators on number of branches per plant

It was explicit from data (Table 4.2) that the number of branches at 30, 60 DAS with the application of phosphorus @ 60 kg/ha was found significantly higher over the application of 40 and 20 kg phosphorus/ha. Application of phosphorus 60 kg/ha increased the number of branches per plant 3.80 and 5.38 at 30, 60 DAS, respectively. While at harvest there were no change in number of branches per plant.

Among the different plant growth regulators application of Ethrel 75 ppm produced significantly higher number of branches per plant at 60 DAS than with NAA and GA_3 (Table 4.2). Application of Ethrel 75 ppm resulted in maximum number of branches per plant 6.28, and was significantly superior to other plant growth regulator treatments which was followed by 20 ppm NAA 5.52 and 50 ppm GA_3 5.02 at 60 DAS. Mean minimum number of branches per plant were observed in water spray. Application of 20 ppm NAA was found at par with 75 ppm Ethrel at 60 DAS.

Among the different treatment combinations, plant growth regulators and phosphorus application at 60 kg phosphorus with 75 ppm Ethrel has produced maximum number of branches per plant 6.82, and was significantly superior to other treatments which was followed by 20 ppm NAA 6.42 and GA_3 50 ppm 5.72 at 60 DAS.

4.1.3 Effect of phosphorus and plant growth regulators on fresh weight of plant (g) per m^2

The perusal of data (Table 4.3) revealed that the application of phosphorus 60 kg/ha significantly increased the fresh weight of plant per m^2 at 30, 60 DAS and at harvest. Higher fresh weight recorded was at 30 DAS 81.23 g per m^2, at 60 DAS 932.69 g per m^2 and at harvest 2610.29 g per m^2. Mean minimum fresh weight per plant at 30

DAS 77.03 g per m^2 , at 60 DAS 896.53 g per m^2 and at harvest 2551.40 g per m^2 in 20 kg phosphorus per ha. RDF has also produced significantly higher fresh weight with increased level of P_20_5 from 924.57g to 962.34.

It was clear from the figures (Table 4.3) that all the plant growth regulators spray significantly increased the fresh weight of crop at 60 DAS and at harvest. The mean maximum fresh weight at 60 DAS 939.21 g/m^2 and at harvest 2620.19 g/m^2 was observed in 50 ppm GA_3 and was at par with 20 ppm NAA at 60 DAS 934.45 g/m^2 and at harvest 2603.65 g/m^2. The mean minimum fresh weight was recorded with the application of water spray at different growth stages.

Among the different treatments combinations, at 60 kg/ha phosphorus and plant growth regulators of 50 ppm GA_3 (T_{14}) spray significantly increased the fresh weight of crop at 60 DAS and at harvest. The mean maximum fresh weight at 60 DAS 981.52 g/m^2 and at harvest 2693.72 g/m^2 was observed and was at par with 25 ppm NAA at 60 DAS 973.22 g/m^2 and at harvest 2679.49 g/m^2.

4.1.4 Effect of phosphorus and plant growth regulators on dry weight of plant (g) per m^2

The data (Table 4.4) explicate that the application of phosphorus 60 kg/ha was significantly increase the dry weight of plant per m^2 at 60 DAS and at harvest. Higher dry weight recorded was 125.91 g per m^2 and 649.96 g per m^2 at 60 DAS and at harvest respectively. Mean minimum dry weight per plant was recorded 119.01 g per m^2 and 630.19 g per m^2 at 60 DAS and at harvest in 20 kg phosphorus per ha. The treatment RDF with increased level of P_20_5 has increased the Dry weight consistently.

It is clear from the figures (Table 4.4) that all plant growth regulators spray significantly increased the dry weight of crop at 60 DAS and at harvest. The mean maximum dry weight per m^2 at 60 DAS 140.88 and at harvest 699.59 was observed in 50 ppm GA_3 and fallowed by 20 ppm NAA 136.42g and 669.13g at 60 DAS and at harvest, respectively. The mean minimum dry weight was recorded with water spray at all the growth stages.

Among the different treatment combinations, 60 kg phosphorus and plant growth regulators with 50 ppm GA_3 significantly increased the dry weight of crop at 60 DAS and at harvest. The mean maximum dry weight per m^2 was at 60 DAS 150.17 g and at harvest 727.30 g (T_{14}) was observed and there was significantly superior to other plant growth regulator treatments with 60 kg phosphorus with 20 ppm NAA at 60 DAS 145.00 g and at harvest 696.66 g.

4.2 YIELD PARAMETERS

Yield characters of fenugreek crop with the influence of treatments are presented in table 4.5 to 4.7 and fig. 4.2 to 4.5.

4.2.1 Effect of phosphorus and plant growth regulators on Days to 50 % flowering

Perusal of data Table 4.5 revealed that application of phosphorus 20 kg/ha was very early for 50 % flowering (46.33 days) while the phosphorus 60 kg/ha took 47.33 days to 50% flowering. The treatment RDF has recorded least number of days for 50 % flowering over other treatments of P_20_5, increase in phosphorus levels has delayed the 50% flowering significantly.

Close study of the Table 4.5 showed that plants sprayed with GA_3 took less time for 50 % flowering as compared to NAA and Ethrel and the difference was significant. The mean minimum of 42.66 days to 50 per cent flowering was recorded with 50 ppm GA_3. The mean maximum of 47.33 days were taken to 50 per cent flowering in water spray (T_6).

4.2.2 Effect of phosphorus and plant growth regulators on number of pods per plant

It was evident from the data Table 4.5 and fig 4.2 that application of 60 kg phosphorus/ha significantly increased the number of pods per plant. The mean maximum number of pods per plant 26.98 was recorded in 60 kg P_2O_5/ha, which was significantly higher over 40 kg P_2O_5/ha (26.21) and at 20 kg P_2O_5/ha 25.47.

All the plant growth regulators had significant influence on number of pods per plant. The mean maximum number of pods per plant were 24.62 was recorded with 20 ppm NAA. The mean minimum number of pods per plant was recorded in water spray(T_4).

Among the different treatment combinations, 60 kg phosphorus with 20 ppm NAA spray significantly affected the number of pods per plant. The mean maximum number of pods per plant 28.49 was recorded with 60 kg phosphorus and 20 ppm NAA, followed by 60 kg phosphorus with 50 ppm GA_3 27.62.

4.2.3 Effect of phosphorus and plant growth regulators on number of seeds per pod

It was evident from data Table 4.5 and fig 4.3 that phosphorus had significant effect on number of seeds per pod. The mean maximum number of seeds per pod 15.02 was recorded with the application of phosphorus 60 kg/ha, which was significantly superior over 20 kg P_2O_5 /ha 14.31. Whereas the RDF has recorded 14.38 seeds/pod and was significantly inferior to increased levels of P_2O_5.

It is obvious from Table 4.5 that spraying of plant growth regulators had significant effect on number of seeds per pod. The mean maximum of seeds per pod 15.02 were recorded with the application of 20 ppm NAA, which was statistically superior among all the growth regulators. However ethrel has reduced the seed/pod significantly. The mean minimum seeds per pod was recorded with water spray.

Among the different treatment combinations, 60 kg phosphorus with 20 ppm NAA significantly affected the number of seeds per pod. The mean maximum number of seeds per pod was recorded with 60 kg phosphorus with 20 ppm NAA is 15.56 (T_{10}). Application of 60 kg phosphorus with 50 ppm GA_3 (15.35). However 60 kg P_2O_5 with ethrel 75 ppm has recorded significantly lower seed yield per pod, but the increased levels of P_2O_5 has significantly increased the seeds per pod.

4.2.4 Effect of phosphorus and plant growth regulators on test weight (g)

Data in the Table 4.6 show that the application of phosphorus significantly increased the weight of 1000 seeds. The mean maximum test weight 13.41 g was recorded in RDF while the mean minimum was recorded 12.42 g in 20 kg Phosphorus/ha (T_{14}). Increased levels of P_2O_5 application has increased the seed test weight.

Its evident from the data Table 4.6 that foliar spray of plant growth regulators had significant effect on test weight. The mean maximum test weight of 13.89 g was recorded in 25 ppm NAA. However, the mean minimum test weight 12.91 g was recorded in Ethrel at 75 ppm. While GA_3 has recorded 13.48 g.

Among the different treatment combinations, 60 kg phosphorus and 20 ppm NAA significantly affected test weight. The mean maximum test weight 14.61 g was recorded with 60 kg phosphorus with 20 ppm NAA. Application of 60 kg phosphorus with 50 ppm GA_3 (T_{14}) 14.19 g was found at par with 20 ppm NAA with 60 kg phosphorus (T_{10}) 14.61.

4.2.5 Effect of phosphorus and plant growth regulators on seed yield (q/ha)

Perusal of data Table 4.6 and fig. 4.4 revealed that the application of phosphorus significantly increased the seed yield of fenugreek. Application of phosphorus 60 kg/ha exhibited its statistical superiority over rest of the treatments with maximum yield of 16.02 q/ha, while 40 kg Phosphorus/ha 15.52 q/ha and 20 kg Phosphorus/ha 15.03 q/ha gave the minimum seed yield. Similar observations were also recorded even in water spray treatments.

A critical examination of data Table 4.6 and fig. 4.4 showed that plant growth regulators produced significant impact on seed yield of fenugreek. NAA proved significantly superior over other plant growth regulators. The mean maximum of 15.25

q/ha seed yield was recorded in 20 ppm NAA fallowed by GA_3. It was further noted that though 75 ppm of Ethrel recorded significant effect on seed yield 14.21 q/ha.

Among the different treatment combinations, 60 kg phosphorus and 20 ppm NAA showed significant impact on seed yield of fenugreek. The mean maximum seed yield 16.70 q/ha was recorded with 60 kg phosphorus with 20 ppm NAA. Application of 60 kg phosphorus with 50 ppm GA_3 was found to be significantly less with 20 ppm NAA and 60 kg phosphorus 16.09.

4.2.6 Effect of phosphorus and plant growth regulators on straw yield (q/ha)

The data on straw yield of fenugreek Table 4.6 and fig. 4.4 indicate the fact that the application of phosphorus 60 kg/ha produced significantly highest straw yield 42.12 q/ha over all other levels of phosphorus. However, the application of 40 kg phosphorus/ha 38.89 q/ha was found significantly higher than the 20 kg phosphorus/ha 34.61 q/ha. Whereas RDF it was 35.120q/ha.

Appraisals of data Table 4.6 reveal that foliar application of growth regulators had significant effect on straw yield over water spray. The mean maximum straw yield, 38.93 q/ha straw yield was recorded with 20 ppm NAA.

Among the different treatment combinations, 60 kg phosphorus with 20 ppm NAA spray significant effect on straw yield of fenugreek. The mean maximum straw yield 48.23q/ha was recorded. Application of 60 kg phosphorus with 50 ppm GA_3 was found at par with 20 ppm NAA and 60 kg phosphorus 43.12 q/ha and T_{18} (P_20_5 60 kg ethrel at 75 ppm).

4.2.7 Effect of phosphorus and plant growth regulators on Biological yield (q/ha)

The data Table 4.7 and fig. 4.5 reveals the significant effect of application of phosphorus on total biomass production by the crop. Phosphorus 60 kg/ha recorded significantly highest biological yield of 55.68 q/ha over other levels of phosphorus. The mean minimum biological yield of 46.06 q/ha was recorded in 20 kg phosphorus/ha while it was 48.24 in RDF.

The figures Table 4.7 and fig. 4.5 indicate that application of 20 ppm NAA recorded significantly higher biological yield 51.37 q/ha fallowed by 50 ppm GA_3 46.41 q/ha and it was least with ethrel at 75 ppm 42.92 q/ha.

Among the different treatment combinations, 60 kg phosphorus with 20 ppm NAA recorded highest biological yield 63.12 q/ha. Application of 60 kg phosphorus with 50 ppm GA_3 58.12 was found at par with 75 ppm ethrel and 60 kg phosphorus 54.54 q/ha.

4.2.8 Effect of phosphorus and plant growth regulators on Harvest index (%)

Data (Table 4.6) clearly indicate that the harvest index was significantly decreased with the application of phosphorus 20 kg/ha (32.45%), which was highest among the other doses of phosphorus. Increased levels of phosphorus has reduced the harvest index proportionately indicating the positive effects on biological yield.

An insight of figures (Table 4.6) obviously shows that plant growth regulators had increased the efficiency of crop to convert biomass into economic yield estimated as harvest index. The significantly highest harvest index (33.10%) was recorded in Ethrel, which was followed by water spray (control). The lowest harvest index (26.45%) was recorded in 20 ppm NAA with 60 kg phosphorus.

4.3 QUALITY PARAMETERS

Quality characters of fenugreek crop under the influence of treatments are presented in table 4.8 to 4.10, analysis of variance of each parameter is given in Appendix III and Fig. 4.13 to 4.16.

4.3.1 Effect of phosphorus and plant growth regulators on nitrogen content (%) of seeds

Data Table 4.8 reveals that nitrogen content of seed was reduced significantly influenced by application of phosphorus. The mean maximum of 2.96 per cent nitrogen content of seed was recorded with the application of 60 kg phosphorus/ha and mean minimum nitrogen content of seed 2.52% was recorded with lower doses of phosphorus 20 kg/ha. However highest nitrogen content was observed in RDF 2.93.

Data Table 4.8 reveals that spray of plant growth regulators significantly enhanced the nitrogen content in seed over water spray. The spray of 20 ppm NAA recorded significantly higher nitrogen content of seed 2.95 % followed by 50 ppm GA_3 2.81 % and 75 ppm Ethrel 2.75%.

Among the different treatment combinations, 60 kg phosphorus with 20 ppm NAA recorded highest nitrogen content in seed 3.01%. Application of 60 kg phosphorus with 50 ppm GA_3 was found at par with 20 ppm NAA and 60 kg phosphorus 3.00 %.

4.3.2 Effect of phosphorus and plant growth regulators on phosphorus content (%) of seeds

The data Table 4.8 indicate that the phosphorus content (%) in seed was significantly influenced by application of phosphorus levels. The highest per cent phosphorus content in seed was recorded under 60 kg P_2O_5/ha 0.50 % while it was minimum 0.43% and 0.48 with T_4 and T_1 under the lower dose of phosphorus 20 kg/ha.

Examination of data Table 4.8 shows that plant growth regulator NAA had significant effect on phosphorus content of seed. The mean maximum phosphorus content in seed 0.51% was recorded with the application of 20 ppm NAA spray. The mean minimum phosphorus content of seed (0.47 %) was observed in 50 ppm GA_3, 75 ppm Ethrel and in water spray.

Among the different treatment combinations, 60 kg phosphorus and 20 ppm NAA recorded highest phosphorus content in seed 0.56%. Application of 60 kg phosphorus (T_{10}) and 50 ppm GA_3 (T_{14}).

4.3.3 Effect of phosphorus and plant growth regulators on potassium content (%) of seeds

Data Table 4.8 reveal that application of phosphorus did not influence the per cent potassium content of seed.

Perusals of data Table 4.8 reveal that application of different growth regulators did not bring significant variation in potassium content (%) of seed. However there was considerable in potassium content of seed with increased levels of P_20_5 application.

4.3.4 Effect of phosphorus and plant growth regulators on chlorophyll content (mg/g)

An examination of data Table 4.9 indicates that the application of phosphorus significantly increased the total chlorophyll content in leaves. Application of phosphorus 60 kg/ha recorded the highest chlorophyll content of leaves both at flowering and pod filling stages 1.52 mg/g, while it was minimum with the application of 20 kg phosphorus/ha at the time of flowering stage 1.33 mg/g and pod filling stage 1.03 mg/g.

Foliar application of growth regulators had significant effect on total chlorophyll content of leaves with mean maximum of (1.42 mg/g) and (1.36 mg/g) at flowering and pod filling stages, respectively was recorded with the foliar application of 20 ppm NAA. The mean minimum total chlorophyll content was recorded in water spray at flowering and pod filling stages, respectively.

Among the different treatment combinations, 60 kg phosphorus and 20 ppm NAA had significant effect on total chlorophyll content of leaves 1.58 %. Application of 60 kg phosphorus with 50 ppm GA_3 was found at par with 20 ppm NAA and 60 kg phosphorus 1.58%.

4.3.6 Effect of phosphorus and plant growth regulators on protein content (%) of seeds

It was inferred from the data Table 4.10 that application of phosphorus had significant effect on estimated protein content of seed. The mean maximum of 21.41 % protein content was recorded with the application of 60 kg phosphorus/ha, while the mean minimum 20.63 % protein content of seed was recorded with the application of 20 kg phosphorus/ha.

Application of growth regulators had a perceptible influence on protein content of seed. The mean maximum of 21.45 % per cent protein content was obtained in 20 ppm NAA that was superior to 50 ppm GA_3 21.13 % and 75 ppm Ethrel 20.25 %. The mean minimum protein content of seeds was observed in water spray.

Among the different treatment combinations, 60 kg phosphorus with 20 ppm NAA highest protein content was obtained 22.61 %. Application of 60 kg phosphorus and 50 ppm GA_3 was found at par with 20 ppm NAA and 60 kg phosphorus 22.21 %.

CHAPTER V

DISCUSSION

In the present chapter, the results of the experiment entitled, "Effect of phosphorus and plant growth regulators on growth, yield and quality of fenugreek (*Trigonella foenum graecum* L.)," have been discussed with the available evidence of literature.

5.1 Effect of Phosphorus

5.1.1 Growth attributes

The growth attributes such as plant height, number of branches per plant, fresh weight of plant per m^2 and dry weight of plant per m^2 were recorded maximum with phosphorus @ 60 kg/ha (Table 4.1, 4.2, 4.3 and 4.4) which may be attributed to better nutritional balance in the root zone as well as in the plant system.

The maximum plant height was observed with increased levels of phosphorus at 60 kg while minimum plant height was observed at 20 kg phosphorus. The highest number of branches per plant was observed at 60 kg phosphorus up to 60 DAS and there was no change at harvest. The higher fresh weight of the plant and dry weight of the plant was recorded with 60 kg of phosphorus. The treatment RDF with increased levels of phosphorus has increased the fresh weight and dry weight of the plant.

The functions of phosphorus in plants is very important. It helps the plant convert other nutrients into usable building blocks with which it grows. Phosphorus is one of the three macro nutrients.

Phosphorus is an important constituent of sugar, phosphates, nucleotide, nucleic acid, coenzymes and phospholipids. The process of anabolism and catabolism of carbohydrates processed when the organic compounds were esterised with phosphoric acid (Cole, 1958).

Phosphates may regulate the enzymatic process. The phosphorylation of ADP to ATP and its dependence on the concentration of phosphosynthates which also act as an activator of some enzymes.

Phosphorus plays an important role in plant bioenergetics. Phosphorus, is essential for the conversion of light energy to chemical energy (ATP) during photosynthesis. Phosphorus can also be used to modify the activity of various enzymes by phosphorylation, and can be used for cell signaling. ATP can be used for the biosynthesis of many biomolecules, which indeed important for plant growth and flower and seed formation. Phosphate esters make up DNA, RNA, and phospholipids. Most common in the form of soil, but it was absorbed most readily in the form of H_2PO_4. Phosphorus availability is limited in most soils because it is released very slowly from the insoluble phosphates.

Many essential functions that phosphorus has in plant metabolic activities are role in energy storage and transfer. Phosphate compounds act as "energy currency" within plants. Energy obtained from photosynthesis and metabolism of carbohydrates stored as phosphatic compounds for subsequent use in growth and reproductive process (Barber, 1980).

The observations of the present investigation are in close confirmity with those of Pareek and Gupta (1981), Mandal and Maiti (1992) in fenugreek, who reported that plant height, number of branches per plant, fresh weight of plant and dry weight of plant increased significantly with the phosphorus fertilization.

Phosphorus plays an important role in the process of photosynthesis, nutrient carrier, and energy transfer. A plant with the proper amount of phosphorus available to it will grow more vigorously and mature earlier than plants with inadequate phosphorus. A plant with phosphors deficiency will exhibit stunted growth, lack of fruit or flowers and wilting of leave. Phosphates esters make up DNA, RNA and phospholipids, most common is the form of polyprotic phosphoric acid (H_3PO_4) in soil, but it is taken up most readily in the form of H_2PO_4. Mixing a phosphorus rich fertilizer with soil when planting will help the plant establish a stable and early root system.

Phosphorus is vital to the growth and health of plants. It assists in converting the sun's energy and other chemicals, such as nitrogen, into usable food for plants. A phosphorus deficiency will lead to stunted, sickly looking plants that produce a lower quality fruit or flower.

5.1.2 Yield attributes and yield

In general, the significant improvement in yield attributes of fenugreek (plant height, number of pods per plant, number of seeds per pod, days to 50 per cent flowering, seed yield, straw yield and biological yield) with the phosphorus fertilization (Table 4.5, 4.6 and 4.7) could be ascribed to overall improvement in vigour and growth of crop.

The increased level of 60 kg phosphates showed negative results in days to 50 % flowering and harvest index and least days to 50 % flowering was observed at 20 kg phosphorus, minimum harvest index also was observed at 20 kg phosphorus.

The number of pods per plant were highest with the application of 60 kg phosphorus and was minimum at 20 kg phosphorus. The application of phosphorus 60 kg/ha produced the maximum number of seeds per pod. It may be due to the reason that phosphorus aids in seed development in legumes. Application of 60 kg the phosphorus produced the maximum 1000 seed weight. The 1000 seed weight increased consistently up to 60 kg phosphorus. Similar observations were also recorded even in water spray treatments. Application of phosphorus at rate of 60 kg has improved the biological yield. However all the yield parameters was observed minimum at the rate of 20 kg phosphorus.

Improved water-use efficiency by phosphorus application increased significantly seeds per pod and also stover yield. It has been found that phosphorus application increases NPK contents, the higher uptake of nitrogen and phosphorus uptake was during seed formation, which resulted in significant increase of seed and straw yield. The higher uptake of nitrogen and phosphorus during seed formation might have increased number of seeds per plant and 1000 seed weight.

The present trend of increase on yield attributes and yield in fenugreek with application of phosphorus @ 60 kg/ha are confirmity with the findings of Khriya and Singh (2003), Jat *et. al.* (1998), Kumar *et. al*. (1999) and Ram and Verma (2000).

5.1.3 Quality attributes

Increased level of phosphorus @ 60 kg/ha increased nitrogen and phosphorus content of seed, chlorophyll content of leaves, protein content of seed (Table 4.7, 4.8 and 4.9). Phosphorus compounds such as lecithin and cephalin appear to be involved in the structural framework of the protoplasm. Thus phospholipids occur as a part of the chloroplast structure. A good supply of phosphorus has been associated with increased root and root hair growth, and early maturity of crops, particularly in grain crop. The effect of ample phosphorus nutrition can be seen on reducing the time required for grain maturity. It was also well known that phosphorus was an essential constituent for synthesis of protein, chlorophyll and other organic compounds of physiological significance in plant system (Samuel *et. al.* 1985). Under the present study marked improvement in phosphorus status of 60 kg/ha might have resulted in higher protein content of seed than 20 kg phosphorus per hectare. The similar kind of findings were also reported by Baboo and Sharma (1995) and Bhunia *et. al.* (2006) in fenugreek.

5.2 Effect of Growth Regulators

5.2.1 Growth attributes

Gibberellic Acid is a hormone that's formed by fermentation (enzyme) activity inside of the plant. One of the major functions of Gibberellic acid are to reverse seed dormancy and cause seed germination. It does so by inhibiting the effects of ABA in the seed.

The result of the present study reported that foliar application of growth regulators significantly improved the growth characters. Among different plant growth regulators applied, 50 ppm GA_3 resulted in maximum plant height, fresh weight of the plant and dry weight of the plant at different growth stages. Gibberellin has been known to play an important role in the germination of seeds. By far the most dramatic effect of gibberellins on plant is their effect on stem elongation intermodal length. Therefore plants treated with GA_3 grow taller. Increase in plant height takes place by two processes-cell elongation and cell division. The cell enlarges and attains its maximum size. This was soon followed by cell division. The daughter cells enlarge and the two processes follow each other closely and contribute to growth (Krishnamoorthy, 1981).

Bhat and Singh (1997) in Okra, EL-Keltwai (2000) in Cumin and Balraj *et. al.* (2002) in Chilli by the foliar application of GA_3 which encourages the growth of plant and gave significantly highest plant height at all stages of growth.

In present investigation, the maximum fresh weight and dry weight of the plant At all stages were recorded with foliar application of 50 ppm GA_3. The maximum number of branches per plant at all stages were recorded in foliar application of 75 ppm Ethrel and was significantly superior to other plant growth regulator treatments.

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5.2.2 Yield attributes and yield

It was observed that in comparison to water spray, foliar spray of growth regulators significantly reduce the days to 50 % flowering and increase the number of pods/plant, seeds/pod, test weight, seed yield, straw yield, biological yield (Table 4.4, 4.5 and 4.6).

Application of 50 ppm GA_3 took minimum (less number of days) days to 50 per cent flowering (Table 4.4 and 4.5). Application of gibberelin is known to induce flowering in large number of plants belonging to diverse response type under conditions in which these plants would, otherwise, remain indefinitely vegetative. Gibberellins are of wide spread occurrence in developing fruit and seeds. In general, the quality of gibberellins present in immature seeds was several times more than in mature parts of the plant body such as the root, stem and leaves. Therefore, developing seeds are extensively used for isolation of gibberellins. The peak growth rate may be due to maximum gibberellins content. Gibberellin brings about a number of physiological changes in plants. However, the mechanism of GA in these processes was less understood.

Application of 20 ppm NAA significantly increased the number of pods per plant, number of seeds per pod, seed yield, test weight, straw yield and biological yield of fenugreek.

There are a few plants in which auxin caused flower formation. In flowering the action of auxin is not direct but is mediated through the formation of ethylene.

Growth stimulators enter the plant system causing improved net photosynthetic rate by increasing CO_2 fixation and by reducing the photorespiration. This hormonal interference at the molecular level is ultimately expressed in the form of the alteration in growth behavior of various morphological components of the plant, which in turn is expressed as yield. (Alagukannan and Vijay kumar, 1999).

5.2.3 Quality attributes

Significant improvement was observed in quality parameters like nitrogen and phosphorus content of seed, protein content of seed, and chlorophyll content of leaves of fenugreek crop under the foliar application of growth regulators (20 ppm NAA), which was closely followed by 50 ppm GA_3 (Krishnamoorthy, 1981).

The present results on chlorophyll content in leaves are in close confermity with those of Medhi (2000) in French bean. Purbey and Sen (2007) also found that the application of NAA 20 ppm increase the N and P content of seed in fenugreek.

Ethylene inhibits leaf expansions and flowering of plants. All phases of flowering, namely, the initiation of primordial, development of flower bud and its opening are affected (Krishnamoorthy, 1981).

The results of the present study, the response of fenugreek (Trigonella foenum-graecum L.) under different levels of phosphours (20, 40and 60 kg P_2O_5/ha) and plant-growth regulators (NAA 20 ppm, GA_3 50 ppm and ethrel 75 ppm) revealed that increase in P level up to 60 kg P_2O_5/ha and significantly increased the yield-attributing characters; and the net returns of fenugreek. The N and P contents of fenugreek in seed and straw and their total uptake increased significantly with increase in the level of applied phosphorus 60 kg/ha, Among different growth-regulators, the application of NAA @ 20 ppm proved significantly better than the GA_3 50 ppm and ethrel 75 ppm.

5.3 Economics of the treatment

The maximum net returns and benefit cost ratio were obtained in 60 kg P_2O_5/ha+20 ppm NAA treatment i.e. (Rs. 3296/ha). This was mainly because of higher seed and biological yield of fenugreek crop under 60 kg P_2O_5/ha and 20 ppm NAA compared to other treatments. While comparing the cost of treatments, GA3 significantly increased the yield but due to higher cost of GA3, the net return was found to be minimum. Thus the treatment combination of 60 kg phosphorus /ha + 20 ppm NAA was found to be the best treatment to increase the yield and quality of fenugreek.

CHAPTER VI

SUMMARY

A field experiment on “Effect of phosphorus and plant growth regulators on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.)” was carried out at Model orchard, College of Horticulture Rajendranagar during the *rabi*, 2010-11.

Treatment consisted of three levels of phosphorus i.e. 20, 40 and 60 kg/ha, three types of plant growth regulators i.e. 20 ppm NAA, 50 ppm GA3 and 75 ppm Ethrel. The experiment was conducted in a randomized block design with 18 treatment combinations, replicated three times, variety “LS-1” was selected for the study. The relevant observation of the effects of the treatments are summarized below:

The significant effect of the phosphorus and plant growth regulators were observed for plant height, number of branches, fresh weight of plant, dry weight of plant, number of pods per plant, number of seeds per pod, test weight, days to 50% flowering, seed yield, straw yield, biological yield, harvest index, N, P, K content of seed, protein content of seed, and chlorophyll content of leaves.

Growth parameters such as plant height, fresh weight and dry weight of the plant were maximum with the treatment 50 ppm GA_3 with phosphorus 60 kg/ha and such growth parameters were minimum with the treatments 75 ppm Ethrel and phosphorus 20 kg/ha. Days to 50 % flowering took less days with 50 ppm GA_3. and the number of branches were highest with 60 kg with ethrel 75 ppm.

Yield attributing characters like number of pod per plant, number of seeds per pod, test weight, seed yield, straw yield and biological yield were maximum with 20 ppm NAA and phosphorus 60 kg/ha and were lowest with the treatment combination 75 ppm Ethrel + phosphorus 20 kg/ha. Harvest index maximum with ethrel.

Phosphorus and plant growth regulators also influenced the quality parameters like N, P content of seed, protein content of seed, chlorophyll content of leaves. "20 ppm NAA with phosphorus 60 kg/ha" treatment combination increase N, P content of seed, chlorophyll content of leaves in fenugreek in comparison to all other treatment combinations.

The highest cost benefit ratio was obtained with the treatment "60 kg Phosphorus /ha and 20 ppm NAA".

Conclusion

On the basis of experimental research findings it could be concluded that the phosphorus and plant growth regulators influence the growth, yield and quality of fenugreek and the cost benefit ratio can be increased with "60 kg Phosphorus/ha + NAA 20 ppm" treatment combination (4.20:1).

Future line of work

The following suggestions are made for further research work.

1. Higher phosphorus levels above 60 kg/ha can be studied.

2. Similarly, the NAA, GA3 and Ethrel levels can be increased and tested in future experiments.

Table 4.1 Effect of phosphorus and plant growth regulators on plant height (cm):

	TREATMENT	Plant height(cm) 30 DAS	Plant height(cm) 60DAS	Plant height(cm) at harvest
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	11.16	30.14	45.97
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	11.70	31.01	48.16
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	12.40	32.86	50.28
T_4	20 kg P2O5 + control (water spray)	10.86	30.04	45.63
T_5	40 kg P2O5 + control (water spray)	11.48	30.96	47.98
T_6	60 kg P2O5 + control (water spray)	12.10	31.82	50.13
T_7	NAA at 20 ppm	9.96	32.10	46.28
T_8	20 kg P2O5 + NAA at 20 ppm	10.78	32.64	47.16
T_9	40 kg P2O5 + NAA at 20 ppm	11.39	33.56	49.24
T_{10}	60 kg P2O5 + NAA at 20 ppm	12.0	34.68	51.42
T_{11}	GA_3 at 50 ppm	10.02	35.02	51.96
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	10.69	35.38	52.14
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	11.32	36.26	54.59
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	12.0	37.21	56.64
T_{15}	Ethrel at 75 ppm	9.82	24.24	40.04
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	10.58	25.68	40.68
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	11.28	26.82	43.24
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	11.90	27.82	45.68
SE (m)±		0.18	0.30	0.69
CD at 5%		0.52	0.83	2.01

Table 4.2 Effect of phosphorus and plant growth regulators on number of branches :

	TREATMENT	Number of branches 30 DAS	Number of branches 60 DAS	Number of branches at harvest
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	2.8	4.68	4.68
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	3.7	5.08	5.08
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	4.0	5.42	5.42
T_4	20 kg P2O5 + control (water spray)	2.6	4.56	4.56
T_5	40 kg P2O5 + control (water spray)	3.5	5.02	5.02
T_6	60 kg P2O5 + control (water spray)	3.8	5.38	5.38
T_7	NAA at 20 ppm	2.5	5.52	5.52
T_8	20 kg P2O5 + NAA at 20 ppm	3.3	5.68	5.68
T_9	40 kg P2O5 + NAA at 20 ppm	3.5	6.08	6.08
T_{10}	60 kg P2O5 + NAA at 20 ppm	3.7	6.42	6.42
T_{11}	GA_3 at 50 ppm	2.4	5.02	5.02
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	3.1	5.06	5.06
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	3.3	5.38	5.38
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	3.6	5.72	5.72
T_{15}	Ethrel at 75 ppm	2.3	6.28	6.28
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	2.9	6.34	6.34
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	3.2	6.48	6.48
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	3.5	6.82	6.82
SE (m)±		0.17	0.14	0.12
CD at 5%		0.45	0.32	0.32

Table 4.3 Effect of phosphorus and plant growth regulators on fresh weight of plant (g/ plant) :

	TREATMENT	Fresh weight (g) 30 DAS	Fresh weight (g) 60 DAS	Fresh weight (g) at harvest
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	77.23	924.57	2601.37
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	79.52	943.29	2631.65
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	81.50	962.34	2658.58
T_4	20 kg P2O5 + control (water spray)	77.03	896.53	2551.40
T_5	40 kg P2O5 + control (water spray)	79.32	914.32	2582.96
T_6	60 kg P2O5 + control (water spray)	81.23	932.69	2610.29
T_7	NAA at 20 ppm	73.96	934.45	2603.65
T_8	20 kg P2O5 + NAA at 20 ppm	77.01	936.27	2623.24
T_9	40 kg P2O5 + NAA at 20 ppm	79.14	954.45	2651.96
T_{10}	60 kg P2O5 + NAA at 20 ppm	81.03	973.22	2679.49
T_{11}	GA_3 at 50 ppm	74.23	939.21	2620.19
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	76.92	944.34	2638.64
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	79.06	963.20	2661.18
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	81.02	981.52	2693.72
T_{15}	Ethrel at 75 ppm	71.12	902.56	2544.82
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	76.28	908.46	2563.14
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	78.69	926.69	2601.36
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	80.72	944.82	2631.29
SE (m)±		0.60	5.51	8.92
CD at 5%		1.76	16.32	26.54

Table 4.4 Effect of phosphorus and plant growth regulators on dry weight of plant (g/ plant):

	TREATMENT	Dry weight(g) 30 DAS	Dry weight(g) 60 DAS	Dry weight(g) at harvest
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	10.81	130.36	660.74
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	11.21	133.94	671.07
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	11.57	137.61	680.59
T_4	20 kg P2O5 + control (water spray)	10.16	119.01	630.19
T_5	40 kg P2O5 + control (water spray)	10.54	122.46	640.57
T_6	60 kg P2O5 + control (water spray)	10.88	125.91	649.96
T_7	NAA at 20 ppm	10.57	136.42	669.13
T_8	20 kg P2O5 + NAA at 20 ppm	11.24	137.63	676.79
T_9	40 kg P2O5 + NAA at 20 ppm	11.38	141.25	686.85
T_{10}	60 kg P2O5 + NAA at 20 ppm	11.66	145.00	696.66
T_{11}	GA_3 at 50 ppm	10.61	140.88	699.59
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	10.92	142.59	707.15
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	11.63	146.40	715.85
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	11.93	150.17	727.30
T_{15}	Ethrel at 75 ppm	10.31	122.74	636.20
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	10.82	124.45	643.34
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	11.25	127.88	655.54
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	11.78	131.32	665.71
SE (m)±		0.11	1.15	2.68
CD at 5%		0.32	3.42	8.02

Table 4.5 Effect of phosphorus and plant growth regulators on days to 50% flowering, number of pods / plant and number of seeds / pod

	TREATMENT	Days to 50% flowering	Number of pods/plant	Number of seeds/pod
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	44.33	25.47	14.38
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	45.00	26.21	14.62
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	45.66	26.98	15.09
T_4	20 kg P2O5 + control (water spray)	46.33	24.62	14.31
T_5	40 kg P2O5 + control (water spray)	46.69	25.50	14.56
T_6	60 kg P2O5 + control (water spray)	47.33	26.21	15.02
T_7	NAA at 20 ppm	44.16	24.62	15.02
T_8	20 kg P2O5 + NAA at 20 ppm	44.66	26.92	15.08
T_9	40 kg P2O5 + NAA at 20 ppm	45.12	27.65	15.29
T_{10}	60 kg P2O5 + NAA at 20 ppm	45.59	28.49	15.56
T_{11}	GA_3 at 50 ppm	42.66	23.31	14.59
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	43.66	26.02	14.63
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	45.00	26.82	15.08
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	44.42	27.62	15.35
T_{15}	Ethrel at 75 ppm	47.00	23.26	13.98
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	47.66	25.12	14.02
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	48.02	26.08	14.32
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	48.66	26.84	14.76
SE (m)±		0.13	0.23	0.09
CD at 5%		0.32	0.65	0.22

Table 4.6 Effect of phosphorus and plant growth regulators on test weight of 1000 seed in (g), seed yield (q/ha) and straw yield (q/ha)

	TREATMENT	Test weight of 1000	Seed yield (q/ha)	Straw yield (q/ha)
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	13.41	15.03	35.12
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	13.83	15.52	39.19
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	13.92	16.02	43.06
T_4	20 kg P2O5 + control (water spray)	12.42	14.95	34.61
T_5	40 kg P2O5 + control (water spray)	12.84	15.46	38.89
T_6	60 kg P2O5 + control (water spray)	13.08	15.91	42.12
T_7	NAA at 20 ppm	13.89	15.25	38.93
T_8	20 kg P2O5 + NAA at 20 ppm	14.09	15.67	40.16
T_9	40 kg P2O5 + NAA at 20 ppm	14.52	16.19	44.14
T_{10}	60 kg P2O5 + NAA at 20 ppm	14.61	16.70	48.23
T_{11}	GA_3 at 50 ppm	13.48	14.96	33.65
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	13.62	15.05	35.18
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	14.06	15.59	39.10
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	14.19	16.09	43.12
T_{15}	Ethrel at 75 ppm	12.91	14.21	32.25
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	13.05	14.32	34.14
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	13.47	14.82	38.24
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	13.50	15.41	42.26
SE (m)±		0.14	0.16	1.29
CD at 5%		0.40	0.42	3.82

Table 4.7 Effect of phosphorus and plant growth regulators on biological yield (q/ha) and harvest index (%)

	TREATMENT	Biological yield (q/ha)	Harvest index (%)
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	48.24	31.15
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	53.26	29.14
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	57.98	27.63
T_4	20 kg P2O5 + control (water spray)	46.06	32.45
T_5	40 kg P2O5 + control (water spray)	51.13	30.23
T_6	60 kg P2O5 + control (water spray)	55.68	28.57
T_7	NAA at 20 ppm	51.37	29.68
T_8	20 kg P2O5 + NAA at 20 ppm	53.26	29.42
T_9	40 kg P2O5 + NAA at 20 ppm	58.12	27.18
T_{10}	60 kg P2O5 + NAA at 20 ppm	63.12	26.45
T_{11}	GA_3 at 50 ppm	46.41	32.23
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	48.26	31.18
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	52.96	29.43
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	58.12	27.68
T_{15}	Ethrel at 75 ppm	42.92	33.10
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	44.86	31.92
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	49.64	29.85
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	54.54	28.25
SE (m)±		1.56	0.54
CD at 5%		4.61	1.57

Table 4.8 Effect of phosphorus and plant growth regulators on N, P and K (%) content of seed

	TREATMENT	N content of seed (%)	P content of seed (%)	K content of seed (%)
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	2.93	0.48	1.02
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	2.98	0.49	1.07
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	3.03	0.52	1.06
T_4	20 kg P2O5 + control (water spray)	2.52	0.43	0.98
T_5	40 kg P2O5 + control (water spray)	2.88	0.47	1.07
T_6	60 kg P2O5 + control (water spray)	2.96	0.50	1.16
T_7	NAA at 20 ppm	2.95	0.51	1.02
T_8	20 kg P2O5 + NAA at 20 ppm	2.90	0.52	1.02
T_9	40 kg P2O5 + NAA at 20 ppm	2.97	0.53	1.07
T_{10}	60 kg P2O5 + NAA at 20 ppm	3.01	0.56	1.16
T_{11}	GA_3 at 50 ppm	2.81	0.47	1.02
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	2.88	0.48	1.02
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	2.93	0.51	1.07
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	3.00	0.53	1.16
T_{15}	Ethrel at 75 ppm	2.75	0.47	0.98
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	2.83	0.47	1.02
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	2.88	0.49	1.07
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	2.95	0.52	1.16
SE (m)±		0.022	0.01	NS
CD at 5%		0.06	0.03	NS

Table 4.9 Effect of phosphorus and plant growth regulators on chlorophyll content of leaves (mg/g) at flowering and pod filling stage

	TREATMENT	Flowering stage (mg/g)	Pod filling stage (mg/g)
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	1.43	1.41
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	1.49	1.48
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	1.54	1.53
T_4	20 kg P2O5 + control (water spray)	1.33	1.03
T_5	40 kg P2O5 + control (water spray)	1.48	1.35
T_6	60 kg P2O5 + control (water spray)	1.52	1.52
T_7	NAA at 20 ppm	1.42	1.36
T_8	20 kg P2O5 + NAA at 20 ppm	1.47	1.45
T_9	40 kg P2O5 + NAA at 20 ppm	1.53	1.53
T_{10}	60 kg P2O5 + NAA at 20 ppm	1.58	1.58
T_{11}	GA_3 at 50 ppm	1.40	1.29
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	1.45	1.41
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	1.51	1.48
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	1.55	1.54
T_{15}	Ethrel at 75 ppm	1.34	1.28
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	1.39	1.34
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	1.45	1.41
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	1.49	1.46
SE (m)±		0.019	0.02
CD at 5%		0.05	0.06

Table 4.10 Effect of phosphorus and plant growth regulators on protein content of seed (%)

	TREATMENT	Protein content (%)
T_1	50 kg N : 20 kg P2O5 : 20 kg K2O	21.03
T_2	50 kg N : 40 kg P2O5 : 20 kg K2O	21.42
T_3	50 kg N : 60 kg P2O5 : 20 kg K2O	21.81
T_4	20 kg P2O5 + control (water spray)	20.63
T_5	40 kg P2O5 + control (water spray)	21.02
T_6	60 kg P2O5 + control (water spray)	21.41
T_7	NAA at 20 ppm	21.45
T_8	20 kg P2O5 + NAA at 20 ppm	21.83
T_9	40 kg P2O5 + NAA at 20 ppm	22.22
T_{10}	60 kg P2O5 + NAA at 20 ppm	22.61
T_{11}	GA_3 at 50 ppm	21.13
T_{12}	20 kg P2O5 + GA_3 at 50 ppm	21.43
T_{13}	40 kg P2O5 + GA_3 at 50 ppm	21.82
T_{14}	60 kg P2O5 + GA_3 at 50 ppm	22.21
T_{15}	Ethrel at 75 ppm	20.25
T_{16}	20 kg P2O5 + Ethrel at 75 ppm	20.63
T_{17}	40 kg P2O5 + Ethrel at 75 ppm	21.02
T_{18}	60 kg P2O5 + Ethrel at 75 ppm	21.41
SE (m)±		0.13
CD at 5%		0.38

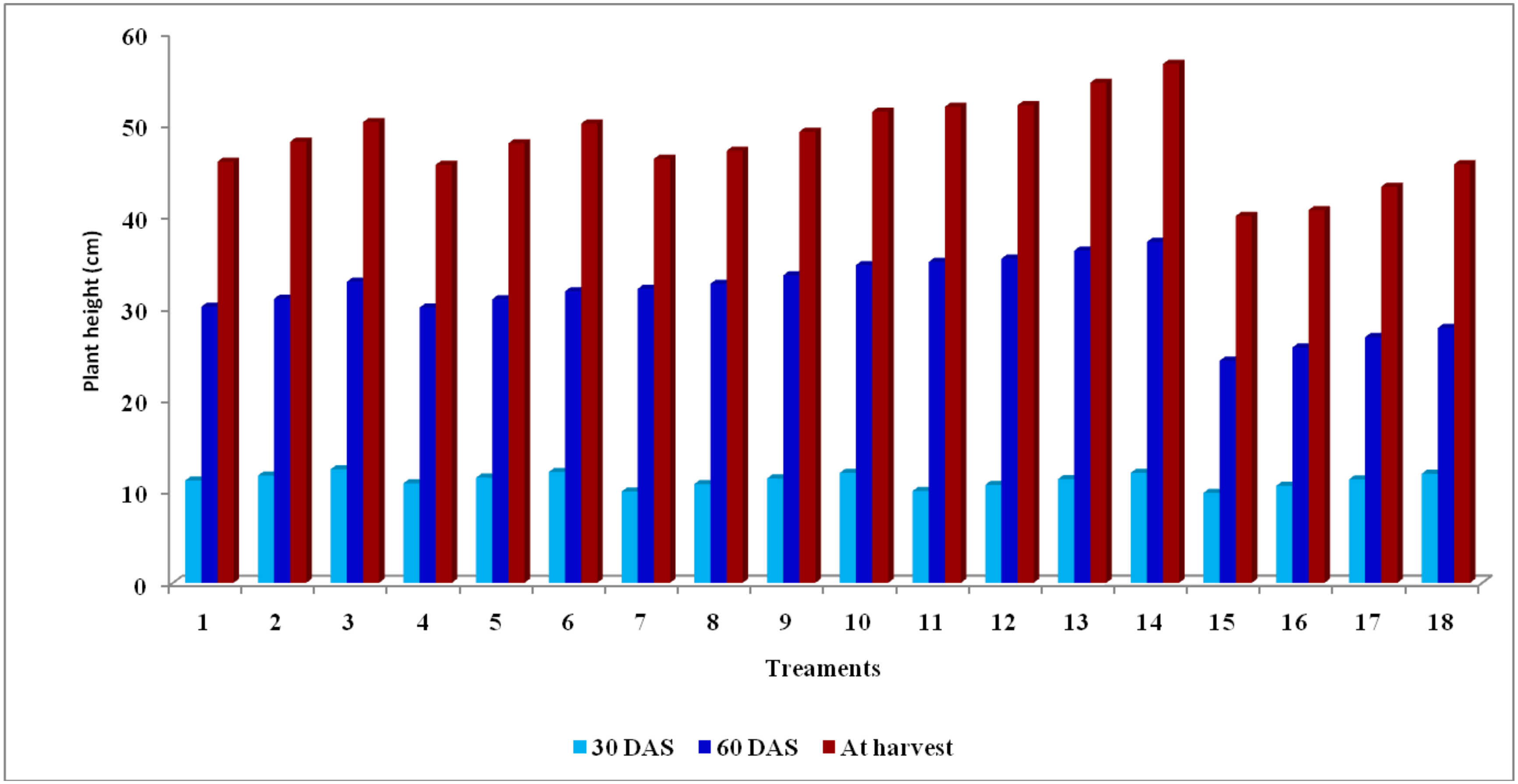

Fig. 4.1 Effect of phosphorus and plant growth regulators on plant height (cm), at 30, 60 DAS and at harvest

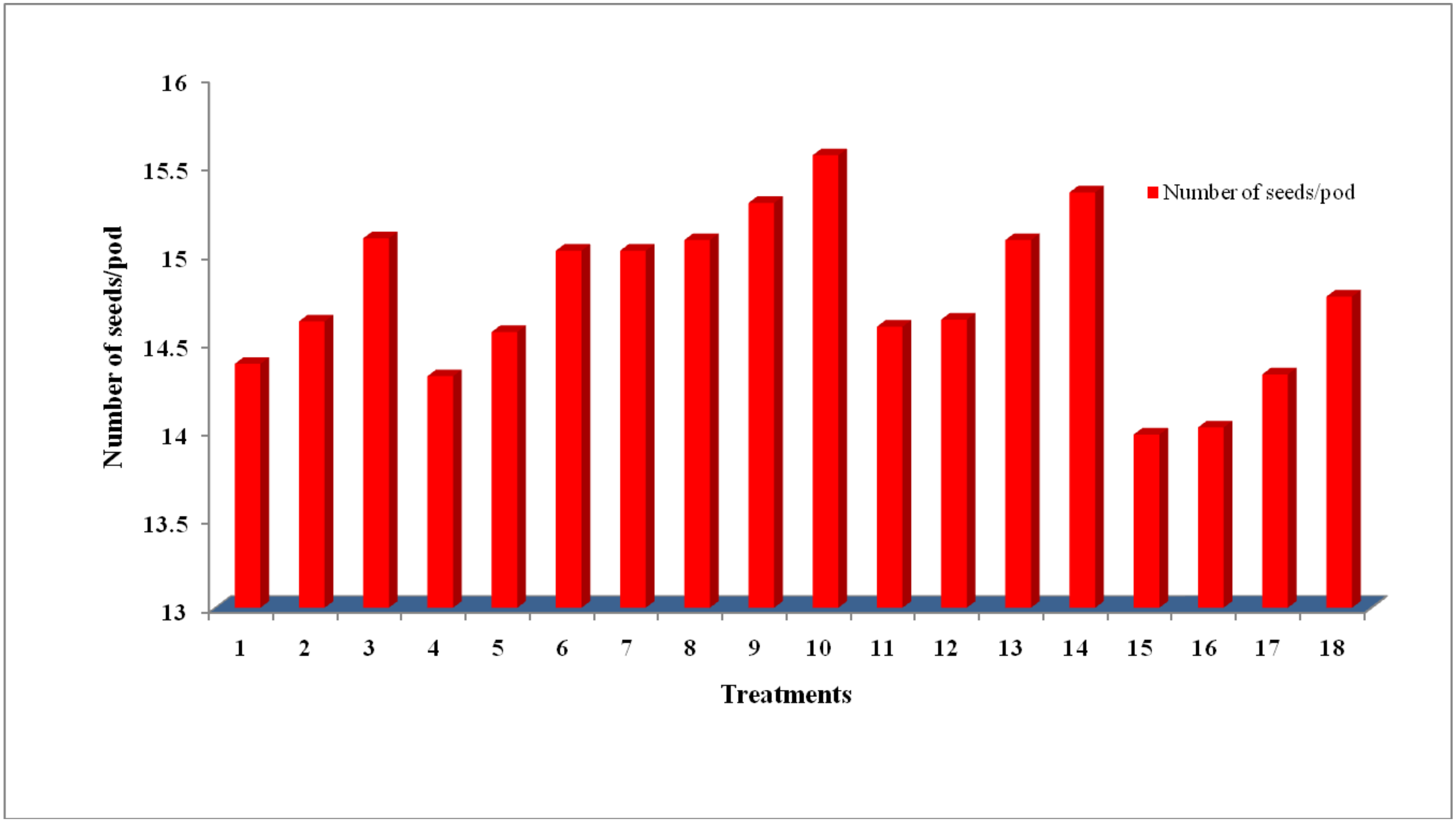

Fig. 4.2 Effect of phosphorus and plant growth regulators on number of seeds / pod

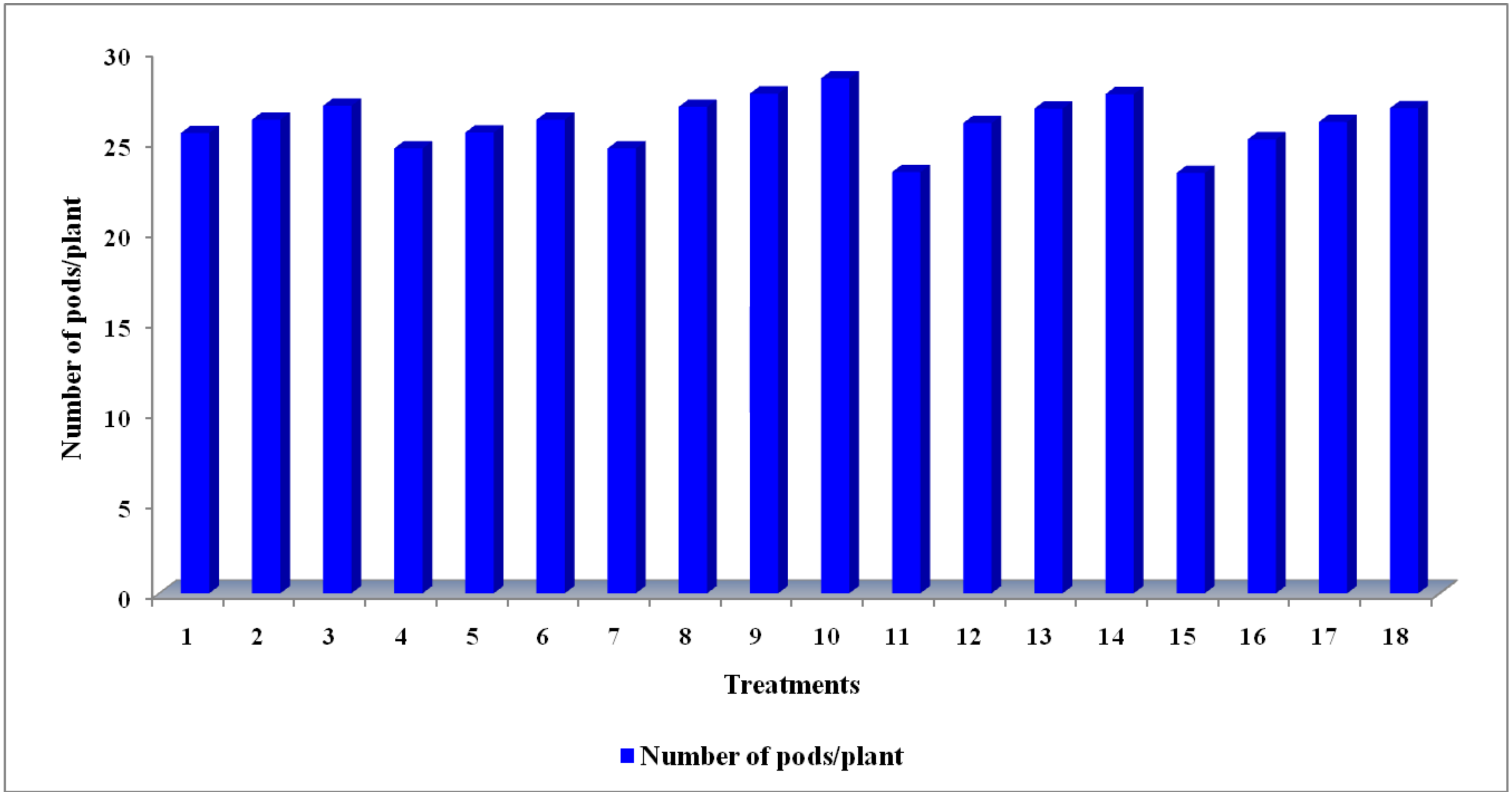

Fig. 4.3 Effect of phosphorus and plant growth regulators on number of pods/plant

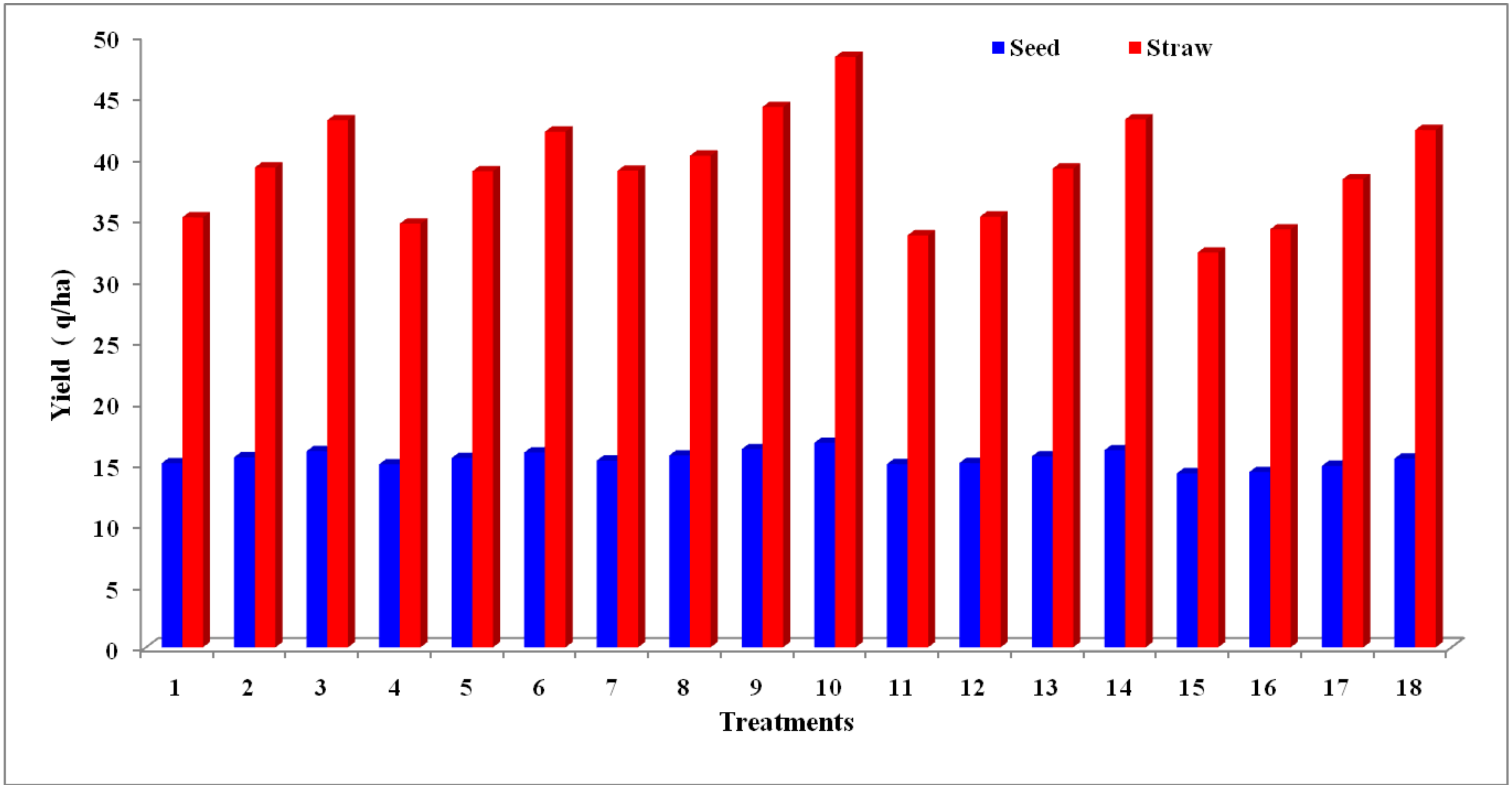

Fig. 4.4 Effect of phosphorus and plant growth regulators on seed yield (q/ha) and straw yield (q/ha)

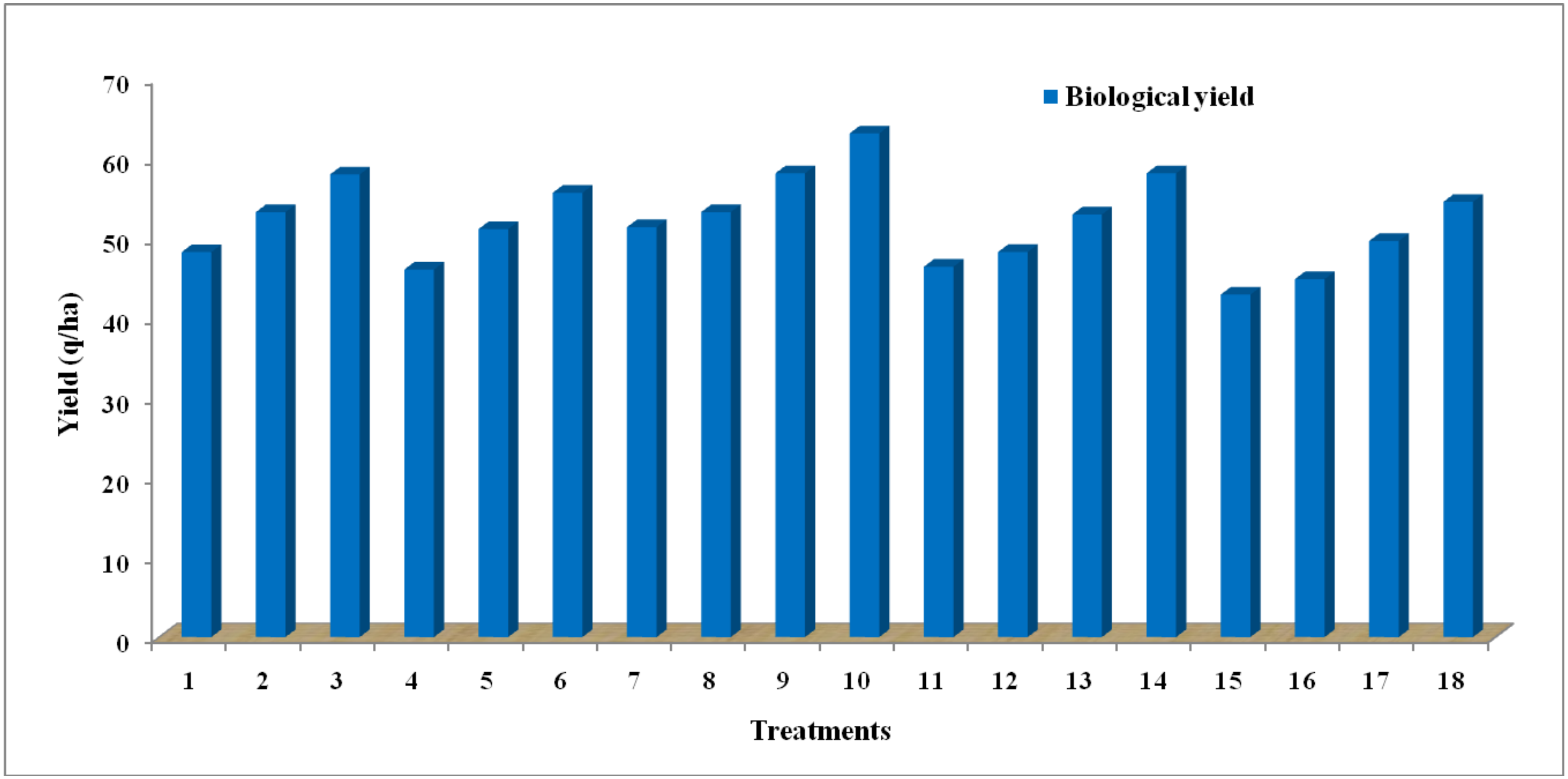

Fig. 4.5 Effect of phosphorus and plant growth regulators on biological yield (q/ha)


T10


T16

Design: RBD
No.of Treatments:16 No.of Repl: 3
Student
Chairman
Assoc. Professor

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APPENDIX-I

Monthly weather data for the year "2010-2011" recorded at Agril. Meteorological observatory, ARI, Rajendranagar

N= Normal (2000-2010)

A= Actual (2010-2011)

Month	RF		T max		T min		BSH		WS		RH I		RH II		Evap.	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
OCT 10	110.0	0.0	30.7	30.1	20.1	20.6	6.5	5.8	2.8	3.0	88.2	86	54.9	63	4.3	2.5
NOV 10	11.3	0.0	29.5	29.5	16.2	15.1	7.5	5.5	2.7	3.0	86.4	93	48.1	66	4.1	2.3
DEC 10	2.3	0.0	28.9	27.8	12.9	13.2	8.1	7.2	2.4	2.7	85.3	86	36.6	44	3.8	2.4
JAN 11	3.2	0.0	29.6	29.5	13.6	10.4	8.4	8.9	2.9	2.4	83.9	84	33.9	29	3.9	2.6
FEB 11	9.8	0.0	32.6	31.2	16.1	15.3	9.2	8.7	3.4	3.4	79.1	83	28.9	35	5.0	2.7

RF-Rain Fall (mm) ; T- Temperature (^{0}C); BSH- Bright Sun Shine Hours (hrs/day) ;

WS- Wind Speed (Km/hr) ; RH-Relative Humidity (%) ; Evap. – Evaporation (mm)