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Determination of appropriate sowing date and phosphorus fertilization strategy for peanut in Eastern India

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Eastern India, which is one of the major contributors in total food production of the country, is facing uncertainties of weather events during the recent years and farmers are encountering agricultural drought like situation, leading to reduction in major food grain production and productivity. To minimize the adverse effect of weather variability on the yield reduction of the major field crops of this area, the referred study was conducted with peanut crop, an alternate cash crop, to evaluate the optimum combination of sowing time and phosphorus fertilization strategy on the potential yield enhancement. Two field experiments were conducted during 2012 and 2013 at Indian Institute of Technology Kharagpur, India. Four sowing dates (14th January, 29th January, 14th February and 28th February) in main plot and four fertilization levels (0 kg P_2O_5 ha^{-1}, 40 kg P_2O_5 ha^{-1}, 60 kg P_2O_5 ha^{-1} and 80 kg P_2O_5 ha^{-1}) in the sub plots were assigned in split-plot design with three replications. The reported study shows that sowing dates in combination with the phosphorus fertilization have less impact on peanut crop, in terms of pod yield, harvest index, shelling percent etc. In this study, higher peanut pod yield (2305.00 and 2285.33 kg ha^{-1}) and shelling percent (73.77 and 83.76) in 2012 and 2013, respectively were obtained during mid to end of February sowing date with application of 40 and 60 kg P_2O_5 ha^{-1} in the sub-humid climate of Eastern India.

Key words: Peanut, weather variability, sowing date, phosphorus fertilizer, pod yield, harvest index, shelling percent, pods per plant

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an important legume cash crop worldwide, due to the high nutritive value of its seeds which is considered to be rich in protein and fats in addition to other vital components. Peanut is an important source of edible oil and protein. It may supplement other protein deficiency in lysine such as cereals, and hence their usage together is fruitful in creating human-food balance especially in developing countries. Moreover, green leafy organs of peanut contain more than 10% protein, which is another important feature of the crop as

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a good fodder for livestock. In India, peanut is grown on 5.31 M ha area with a production of 6.93 m MT, with an average productivity of 1.30 MT ha^{-1}, during post rainy season (Agricultural Statistics at a Glance, 2012).

In India, rice (*Oryza sativa*) is the major *kharif* (rainy season) crop and rice based cropping sequence is predominant, mainly in the eastern part of the country. For growing rice, plenty of water, huge amount of chemical fertilizers and pesticides are applied to increase the crop yield, which is causing over-exploitation of groundwater resources and deterioration of soil health. Therefore, appropriate management of natural resources, alternate cropping system or multiple cropping sequences are considered to be the best management practice to restore the resources. Peanut can replace the potential rice cultivated areas and can improve the soil health by adding atmospheric nitrogen through its nodulation. It also requires lesser irrigation, thereby resulting in water saving. Growing of peanut as summer crop (end of January to April) or as monsoon (*Kharif*) crop (June to October) in place of rice can change the present scenario and simultaneously can improve the economy of the country. In South India, November is considered as the best sowing time of the *rabi* peanut on residual soil moisture, and sowing between December to end of January is most suitable sowing time to get higher yield of irrigated peanut crops. Different sowing dates in summer season significantly influence the peanut dry pod yield, shelling percentage and test weight. The highest dry pod yield was recorded with 16th January sown crop (2694 kg ha^{-1}) as compared to 1st January (2537 kg ha^{-1}) and 31st January sowing (2340 kg ha^{-1}). On contrary, the shelling percent and test weight was significantly higher in 1st January sowing (65.70% and 34.60 g, respectively), than that of 16th January sowing (64.40% and 34.30 g) and 31st January sowing (61.80% and 32.70 g), respectively (Attarde et al., 2001a).

Though phosphorus is considered as second major nutrient after nitrogen (Gervey, 1987) in plant essential nutrients list, it plays an important role in crop growth and development and ensures good yield (Sharma and Yaday, 1997). According to Balasubramanian et al. (1980), application of phosphorus fertilizer results in better nodulation and seed yield of legumes. Prihar and Tripathi (1989) reported that application of nitrogen and phosphorus fertilizers can increase total dry matter accumulation by enhancing growth attributing characters (viz. root growth, leaf area, shoot growth, branching). Deshmukh et al. (1993), Nasr-Alla et al. (1998) and El-Habbasha et al. (2005) reported that, increase of phosphorus and potassium fertilization independently or combination can increase the yield and yield attributes of peanut. Bhatol et al. (1994) also found that nitrogen fertilizer decreased the oil content of groundnut, while phosphorus fertilizers can increase the yield and quality significantly with the increasing rate of 30 to 60 kg P_2O_5 ha^{-1} (Gobarah et al., 2006).

Keeping these facts in mind, the present study was conducted to assess the effect of planting time and different levels of fertilization on performance of peanut crop in the Eastern Indian condition, and to determine the appropriate combination of planting time and phosphorus fertilization levels to acquire maximum yield of peanut.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted during two consecutive summer seasons (January to April), in 2012 and 2013 at the Department of Experimental Farm of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur, India, (22.19° N latitude and 87.19° E longitude, altitude 48 m above the mean sea level) to investigate the response of the selected peanut variety (TMV-2) to different combinations of planting dates and phosphorus fertilization levels.

Climatic condition

The experiment site is sub-humid, subtropical with hot and humid summer (April and May), rainy during June to September, moderately hot and dry in autumn (October and November), cool and dry in winter (December and January) and moderate is spring (February and March). The site receives an average annual rainfall of 1200 mm, out of which 70 to 75% occurs in the monsoon seasons of June to October. The average temperature varies between 21 and 32°C. During the 2012 cropping season (2nd week of January to 2nd week of May), a total amount of 166.57 mm rainfall was recorded in the Automatic Weather Station, installed at the experimental site, whereas, during the 2013 cropping season, a total of 103.8 mm rainfall was received. During the 2012 crop growing season, the maximum and minimum temperatures varied between 24.5 to 40.1°C and 14.7 to 24.4°C, respectively with mean temperature varying from 19.6 to 32.2°C. Whereas during the 2013 crop growing season, it varied between 24.2 to 33.4°C, 12.8 to 28.7°C and 18.6 to 30.3°C, respectively (Figure 1). The average relative humidity (%) during peanut growing period that is, Av RHI (morning time) and Av RHII (evening time) varied between 49.82 to 70.71% and 34.54 to 53.33% in the year 2012. During 2013 cropping period, the RH values (RHI and RHII) varied between 65.54 to 78.75% and 38.30 to 63.21%.

Soil character

The study area is situated in red and laterite zone of West Bengal with sandy loam textured soil, which is taxonomically grouped under the group ‘Alfisol’. The physical properties are presented in Table 1.

Description of cultivar

Peanut

TMV-2, a Spanish variety evolved at Tindivanum, Tamil Nadu, India by mass selection from local cultivar Gudiatham was used as the experimental crop. It is a bunch and non-dormant variety with crop growing period of 105 to 110 days. Its yield potential is 3000 kg ha^{-1} under irrigated conditions with a shelling percent of 76.7 and oil content of 46.0%.

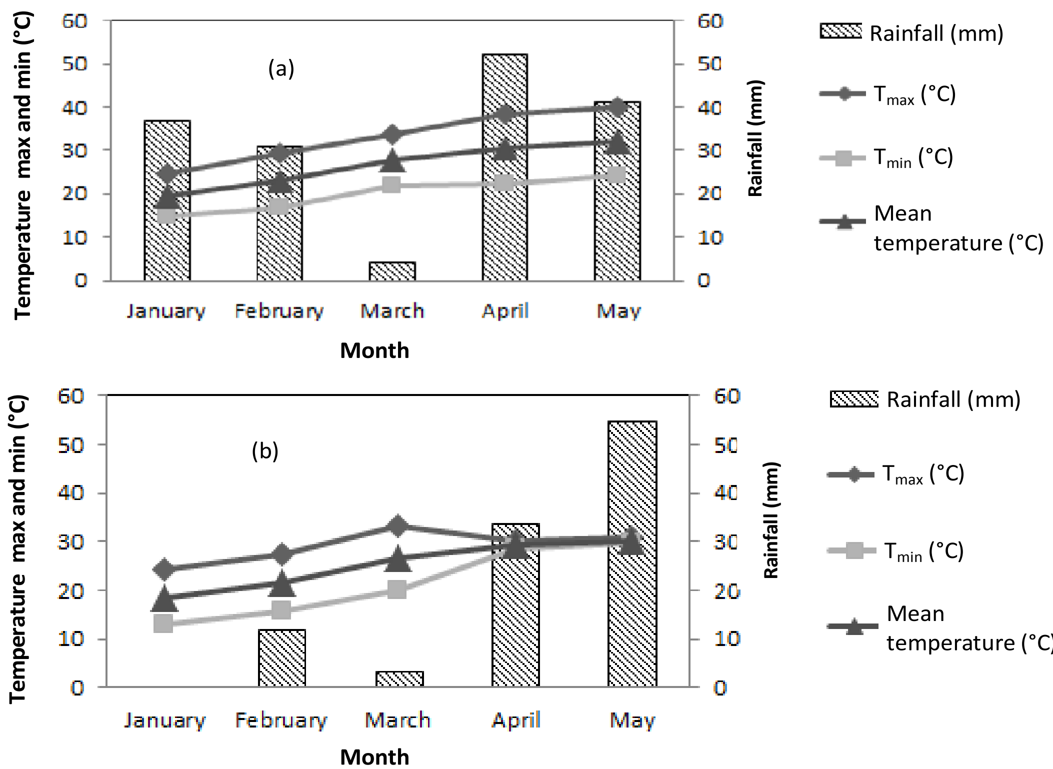

Figure 1. Weather parameters during Peanut cropping period (January to May) of (a) 2012 and (b) 2013.

Table 1. Physical properties of different soil profiles of the experimental crop field used for experimental crops.

Soil depth (cm)	Particle size distribution (%)			Bulk density (g/cm)	Saturated hydraulic conductivity (cm/day)
	Clay	Silt	Sand		
0 - 15	14.3	26.2	59.5	1.69	9.84
15 - 30	21.0	19.3	59.7	1.56	6.72
30 - 45	27.3	20.2	52.5	1.59	0.89
45 - 60	28.6	19.2	52.2	1.63	0.74
60 - 90	29.7	24.7	45.6	1.69	0.34

Source: Kashyap (2001).

Experimental details

Treatment details

The treatment details are depicted as follows:

Factor I (Sowing dates): (i) p_1: 14th January; (ii) p_2: 29th January; (iii) p_3: 13th February and (iv) p_4: 28th February.

Factor II (Fertilization level, kg ha^{-1}): (i) q_1: Control (N: P_20_5 : K_2O:: 0:0:0); (ii) q_2: N: P_20_5: K_2O:: 20: 40: 40; (iii) q_3: N: P_20_5: K_2O:: 20: 60: 40 and (iv) q_4: N: P_20_5: K_2O:: 20: 80: 40.

Experiment design

Field experiments were laid out in the split-plot design, with three replications and a total of 48 plots. The experiment consisted of 16 combinations of treatments viz. 4 planting dates and 4 levels of phosphorus fertilizer. Planting dates were considered in the main plot as the first factor and fertilization levels in the sub-plot as the second factor. The individual plot size was 5.0 × 4.0 m, each plots were separated by 60 cm border strip, and the row to row and plant to plant distance considered was 30 × 20 cm.

Cultural operation

Land preparation

The experimental field ploughed 3 to 4 times followed by harrowing, just to get good tilt. Well-rotted farm yard manure (FYM) at 10 t ha^{-1} was applied and mixed with the soil at the time of final land preparation.

Fertilizer application

Nitrogen (N), phosphorus (P) and potassium (K) fertilizers were applied in the form of urea (46% N), single super phosphate (16% P_2O_5) and Muraite of potash (60% K_2O), respectively. Half of each recommended level of urea and entire quantity of recommended levels of phosphorus and potassium fertilizer (20:40:40, 20:60:40 and 20:80:40) were applied at the time of sowing. Remaining 3/4th of urea fertilizer was applied in two splits, once after 30 days after sowing (DAS) and another at 45 DAS.

Seed treatment and after care

Before sowing, the seeds were treated with *Rhizibium* culture at 25 gm kg^{-1} seeds and were sown in shallow furrows at 5 cm depth with 30 × 20 cm spacing. All the regular agricultural management practices were followed during the 2 years of crop experiments. For control of late leaf spot and leaf rust the crop was sprayed with carbendazim (50% WP) at 0.5 g lit^{-1} and Mancozeb (75% WP) at 45 and 60 DAS, respectively.

Irrigation

Irrigation scheduling was done based on the available soil moisture level using time demain reflectometer (TDR) (Martin et al., 1990) and Gravimetric methods. Field capacity moisture percentage was maintained through out the crop growing period.

Harvesting

The crop was harvested at physiological maturity (100 DAS). Entire population of plants in 1 m^2 area were uprooted from the net plot area of each treatment separately and spread in the field for drying. The pods were plucked from the plants. All dirt, soil impurities, and immature pods were removed and developed pods were completely sun-dried for a period of 1 week.

Data collection

Growth and yield parameters

The growth and yield parameters of plants namely: plant height (cm), number of branches/plant, above ground dry matter (ADM)/plant, number of pods/plant, pod yield m^{-2} and leaf area index (LAI) were measured at 25, 50 and 75 DAS. During harvest, 16 plant samples from 1 m^2 area of each treatment and each replication were taken to determine the plant charecteristics by averaging the above mentioned paramenters, in addition to the final dry pod yield (kg ha^{-1}), harvest index (HI), shelling percent and test weight.

The shelling percentage of the graded pods was calculated by using the following formula:

$$\text{Shelling percentage} = \frac{\text{Weight of graded pods (g) – weight of husk}}{\text{Total weight of graded pods (100 g)}} \times 100$$

Harvest index was calculated using the following formula:

$$\text{Harvest index} = \frac{\text{Economic yield (g/m}^2\text{)}}{\text{Biological yield (g/m}^2\text{)}}$$

Statistical analysis

The effects of the different factors (4 planting dates and 4 levels of phosphorus fertilizers) and their interactions were studied in one experiment with same precision by dividing each block into a number of plots equal to the number of treatment combinations in these plots. The significance of different sources of variation was tested by “error mean square” by Fisher and Snedecors F-test at 5% level of significance (P = 0.05). Comparison of F-tables and computation of critical differences (CD) at P = 0.05 were made using the Fisher and Yates table. Statistical analysis and interpretation of results were made by calculating values of standard error means (SEM) and CD at 5% level of significance. The SEM, and the value of CD used to compare the difference between means is presented in each of the table (Tables 2 and 3) of results.

RESULTS

Effect of sowing dates, phosphorus fertilization levels and their interactions on growth parameters of peanut

Effect of sowing dates

The growth parameters viz. plant height, number of branches per plant, LAI and ADM were measured at 25, 50 and 75 DAS during 2012 and 2013 crop growing season. During both the crop growing season almost similar trend was noticed in the growth parameters (Tables 2 and 3). Significant differences among all growth parameters were found in all the four sowing dates, except LAI. During both the crop seasons p_2 (28th January), p_3 (14th February) and p_4 (28th February) were mostly found to have large deviation with the shifting of sowing dates. Highest LAI (1.97) was recorded with p_1 and p_4 (14th January and 28th February) date of sowing at 75 DAS during 2012, however, the highest ADM (16.5 g m^{-2}) was obtained with p_3 (14th February) sowing dates at 75 DAS. During 2013, the highest LAI (2.46) and ADM (38.45 g m^{-2}) were found at 75 DAS with p_4 (28th February) date of sowing.

Effect of phosphorus fertilization

There was no significant effect of phosphorus fertilization on growth parameters of peanut during 2012. Only plant height and ADM varied significantly due to the variation in levels of phosphorus fertilizer at 75 DAS (Table 3). On the other hand, during 2013, all the growth parameters exhibited significant variations due to variation in phosphorus fertilization level. Highest plant height (34.83 cm), number of branches (21.10), LAI (2.45) and ADM (33.62 g m^{-2}) were recorded by q_4 (80 kg P_2O_5 ha^{-1}) fertilization level at 75 DAS (Table 3). The results reveal that all these parameters were the principal constituents which control the biomass accumulation. Moreover, increase in phosphorus fertilization levels (q_3: 60 kg ha^{-1} and q_4: 80 kg ha^{-1}) also plays a significant role in improvement of all the growth parameters.

Table 2. Effect of sowing dates, phosphorus fertilization levels and their interaction on plant height, number of branches, Leaf Area Index (LAI) and above ground dry matter (ADM) of peanut for 2012 season.

Treatment	25 DAS				50 DAS				75 DAS			
	Plant height (cm)	Number of branches	LAI	ADM (g/m^2)	Plant height (cm)	Number of branches	LAI	ADM (g/m^2)	Plant height (cm)	Number of branches	LAI	ADM (g/m^2)
Sowing dates (p)												
p_1 (14th January)	11.65	6.00	0.20	0.77	18.67	7.00	0.45	1.10	33.4	12.3	1.97	11.4
p_2 (29th January)	13.58	5.90	0.23	0.60	17.63	8.00	0.54	1.10	48.2	16.8	1.66	11.3
p_3 (14th February)	8.34	6.80	0.17	2.32	42.72	13.50	1.67	8.10	59.0	21.0	1.74	16.5
p_4 (28th February)	10.79	6.80	0.15	1.80	34.70	14.50	0.83	8.60	58.6	21.8	1.97	12.1
SEM	0.35	0.18	0.06	0.08	0.63	0.19	0.04	0.18	1.86	0.59	0.13	0.40
CD (P = 0.05)	1.22	0.64	NS	0.28	2.17	0.65	0.15	0.64	6.43	2.04	NS	1.40
Phosphorus fertilizer (q)												
q_1 (P_2O_5 = 0 kg/ha)	10.73	6.30	0.18	1.36	27.36	10.75	0.82	4.60	48.90	17.9	1.39	11.1
q_2 (P_2O_5 = 40 kg/ha)	10.7	6.30	0.20	1.36	28.41	10.92	0.86	4.40	48.00	17.8	1.78	12.3
q_3 (P_2O_5 = 60 kg/ha)	11.38	6.50	0.18	1.24	28.71	10.50	0.92	5.10	49.70	17.8	1.98	13.4
q_4 (P_2O_5 = 80 kg/ha)	11.51	6.50	0.19	1.52	29.24	10.83	0.90	4.70	52.60	18.3	2.19	14.4
SEM	0.27	0.11	0.01	0.10	0.78	0.26	0.04	1.94	0.80	0.30	0.06	0.32
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	2.23	NS	NS	0.95
Interactions (p × q)												
p_1q_1	11.33	6.0	0.19	0.93	18.10	7.33	0.44	1.10	31.0	11.0	1.46	7.60
p_1q_2	11.60	6.0	0.20	0.86	17.63	6.67	0.38	1.10	34.3	12.7	2.03	12.2
p_1q_3	11.59	6.0	0.21	0.50	18.93	7.33	0.47	1.40	33.7	12.0	2.23	13.2
p_1q_4	12.07	6.0	0.19	0.76	20.00	6.67	0.49	1.00	34.6	13.7	2.16	12.5
p_2q_1	13.40	5.7	0.23	0.56	17.50	8.00	0.47	1.00	45.7	17.0	1.28	11.4
p_2q_2	13.30	6.0	0.23	0.64	17.13	8.33	0.48	1.00	42.7	17.0	1.25	10.2
p_2q_3	14.03	6.0	0.23	0.49	17.70	7.67	0.57	1.10	47.1	16.0	1.58	9.70
p_2q_4	13.6	6.0	0.24	0.66	18.20	8.00	0.64	1.10	57.5	17.0	2.52	13.7
p_3q_1	8.00	7.0	0.15	1.92	39.33	13.33	1.59	6.70	59.3	21.0	1.37	14.3
p_3q_2	7.70	6.3	0.16	2.34	42.00	13.33	1.79	7.70	57.3	20.7	1.80	14.9
p_3q_3	8.17	7.0	0.17	2.29	43.37	13.00	1.77	9.40	58.8	21.0	1.89	18.2
p_3q_4	9.50	7.0	0.19	2.72	46.17	14.33	1.51	8.50	60.5	21.3	1.90	18.7
p_4q_1	10.17	6.3	0.16	2.02	34.50	14.33	0.78	9.50	59.5	22.7	1.46	11.0
p_4q_2	10.40	7.0	0.20	1.57	36.87	10.92	0.77	8.00	57.5	21.0	2.03	11.7
p_4q_3	11.73	7.0	0.13	1.68	34.83	10.50	0.85	8.70	59.3	22.0	2.23	12.7
p_4q_4	10.87	7.0	0.13	1.96	32.60	10.83	0.94	8.40	57.8	21.3	2.16	13.1

Table 2. Contd.

SEM	0.52	0.24	0.02	0.17	1.28	0.40	0.08	1.94	1.22	0.72	0.16	0.61
CD (*P* = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	3.66	NS	0.51	1.93

Table 3. Effect of sowing dates, phosphorus fertilization levels and their interaction on plant height, number of branches, leaf area index (LAI) and above ground dry matter (ADM) of peanut for 2013 season.

Treatment	25 DAS				50 DAS				75 DAS			
	Plant height (cm)	Number of branches	LAI	ADM (g/m^2)	Plant height (cm)	Number of branches	LAI	ADM (g/m^2)	Plant height (cm)	Number of branches	LAI	ADM (g/m^2)
Sowing dates (p)												
p_1 (14th January)	5.03	7.00	0.17	0.38	13.03	11.80	0.83	3.12	21.73	18.20	1.18	16.25
p_2 (29th January)	6.92	6.90	0.13	0.92	14.25	10.30	0.82	8.11	26.98	20.10	2.42	21.81
p_3 (14th February)	5.90	8.20	0.13	1.20	15.31	13.80	2.31	26.61	30.42	18.60	1.74	23.96
p_4 (28th February)	6.38	9.10	0.19	2.02	23.23	15.80	0.95	12.62	39.08	18.00	2.42	38.45
SEM	0.21	0.10	0.03	0.29	0.57	0.18	0.14	2.83	1.62	1.05	0.24	3.33
CD (*P* = 0.05)	0.75	0.37	NS	1.00	1.95	0.63	0.49	9.80	5.61	NS	0.82	11.54
Phosphorus fertilizer (q)												
q_1 (P_2O_5 = 0 kg/ha[1])	5.14	7.50	0.17	1.51	13.23	11.40	1.20	11.31	24.50	16.90	1.57	18.63
q_2 (P_2O_5 = 40kg/ha)	5.77	7.80	0.17	1.81	15.67	12.40	1.32	12.32	28.27	18.30	1.70	21.93
q_3 (P_2O_5 = 60kg/ha)	6.14	7.80	0.13	1.95	17.37	13.90	1.26	12.73	30.61	18.50	2.05	26.29
q_4 (P_2O_5 = 80kg/ha)	7.17	8.10	0.14	2.23	19.55	13.80	1.13	14.10	34.83	21.10	2.45	33.62
SEM	0.19	0.11	0.01	0.08	0.38	0.19	0.12	0.44	0.79	0.41	0.38	0.77
CD (*P* = 0.05)	0.56	0.33	NS	0.25	1.12	0.57	NS	1.28	2.31	1.22	1.19	2.25
Interactions (p × q)												
p_1q_1	4.67	7.00	0.14	0.32	10.47	9.00	0.77	2.99	17.50	15.00	1.33	13.04
p_1q_2	4.60	7.00	0.17	0.37	12.30	10.30	0.95	2.48	23.13	19.30	1.03	13.50
p_1q_3	4.67	7.00	0.19	0.39	14.50	13.30	0.94	3.54	21.27	17.30	0.73	17.93
p_1q_4	6.17	7.00	0.19	0.43	14.83	14.30	0.67	3.49	25.00	21.00	1.64	20.55
p_2q_1	6.00	6.70	0.16	0.83	10.70	8.30	0.60	7.95	22.83	17.00	1.26	13.61
p_2q_2	6.50	7.00	0.13	0.98	14.30	9.30	0.71	8.59	24.27	19.00	1.38	23.16
p_2q_3	7.00	7.00	0.10	0.93	15.63	12.30	1.10	7.90	27.17	19.30	3.03	26.39
p_2q_4	8.17	7.00	0.13	0.92	16.37	11.00	0.88	8.00	32.67	25.00	4.02	24.09
p_3q_1	4.73	8.00	0.17	2.52	14.17	13.30	2.34	23.83	25.33	18.30	1.37	15.95
p_3q_2	6.13	8.00	0.13	3.81	14.40	14.00	2.27	24.43	28.33	17.00	1.80	15.60
p_3q_3	6.40	8.30	0.09	5.25	15.50	14.00	2.14	27.04	32.00	19.30	1.89	18.94

Table 3. Contd.

p_3q_4	6.33	8.30	0.12	5.23	17.17	14.00	2.03	31.12	36.00	19.70	1.90	45.34
p_4q_1	5.17	8.30	0.23	2.38	17.60	15.00	1.09	10.48	32.33	17.30	2.33	31.92
p_4q_2	5.83	9.00	0.26	2.10	21.67	16.00	0.91	13.78	37.33	18.00	2.58	35.48
p_4q_3	6.50	9.00	0.12	1.23	23.83	16.00	0.87	12.43	41.00	18.00	2.54	41.92
p_4q_4	8.00	10.00	0.14	2.36	23.83	16.00	0.94	13.78	45.67	18.70	2.25	44.50
SEM	0.35	0.92	0.03	0.32	0.78	0.33	0.23	2.90	1.97	1.20	0.38	3.51
CD (P = 0.05)	NS	NS	NS	1.06	2.50	1.02	NS	9.97	NS	4.02	1.19	11.96

Interaction

All the growth parameters were influenced by the combination of sowing dates and phosphorus fertilization level during both the years of experimentation. During first year of experiment (2012), highest plant height (60.5 cm) and ADM (18.7 gm^{-2}) was obtained with the interaction of p_3q_4 treatment and branch number (22.7) and LAI (2.52) were also recorded at 75 DAS with p_4q_1 and p_2q_4 treatment combination (Table 2).

However, during second year (2013), the highest value of ADM (45.34 g m^{-2}) was obtained for the p_3q_4 combined treatment. The maximum number of branches (25.0) was obtained with p_2q_4 treatment combination, whereas, maximum LAI (4.02) was found at 75 DAS with p_4q_4 and p_2q_4 treatment combination, respectively (Table 3).

Effect of sowing dates, phosphorus fertilization levels and their interaction on yield parameters of peanut crop

Effect of sowing dates

The effect of sowing dates on the yield parameters viz. pods per plant, pod yield, harvest index, shelling percent and test weight of peanut during experiment are presented in Figure 2a to e. Significant difference was found in pods per plant, pod yield, shelling percent and test weight during 2012 and 2013 crop growing season (Figure 2b, d and e). From Figure 2a, it can be revealed that during 2012 the number of pods per plant was higher than 2013 but followed almost the same trend during both the cropping season. For pod yield (Figure 2b), the slightly highest yield (2305 kg ha^{-1}) was found during 2012 with p_2 (29th January). The average pod yield of the two year experiment shows that, in the second year yield reduction was 1.50% from the first season due to the unavailability of rainfall at the early stage of crop growth during the second year experiment. On the other hand, a considerable difference was found for shelling percent and test weight (g) among the four sowing dates as shown in Figure 2d and e during both the crop growing season. From figure 2d, it can be seen that during 2013 crop experiment, the shelling percent was higher than 2012 crop experiment with the shifting of sowing dates from p_2 to p_4, with the highest shelling percent of 74.45%. In case of test weight, the value was higher during 2012 than 2013 for first three sowing dates, with the highest value of 37.61 for p_2 (29th January) sowing date.

Effect of phosphorus fertilization levels

The effect of different phosphorus fertilization levels on peanut yield parameters are presented in Figure 3a to e. It can be revealed from the Figure 3a that during 2012 cropping season, the pods per plant increased with the increase in phosphorus fertilization level up to q_3 (60 kg P_2O_5 ha^{-1}), whereas during 2013 cropping season, pods per plant has increased up to q_4 fertilization level. The slow increase of pod per plants may be because of the use of slow releasing phosphorus fertilizer (coated granular phosphorus) which showed late response in crop yield. Moreover, a significant difference can be seen between both the cropping seasons due to the variation in the levels of phosphorus fertilization. It was also found that the pod yield, harvest index and test weight did not show any difference during both the cropping period and followed the same trend with the increase in phosphorus fertilization levels.

Interaction

Figure 4a to e shows the combined effect of both sowing dates and phosphorus fertilization levels during 2012 and 2013 crop growing seasons. The sowing dates and phosphorus fertilization levels together have no significant effect on yield and yield attributes during 2012 and 2013 crop growing period. Highest pods per plant (53.7) recorded with p_3q_3 treatment combination in the

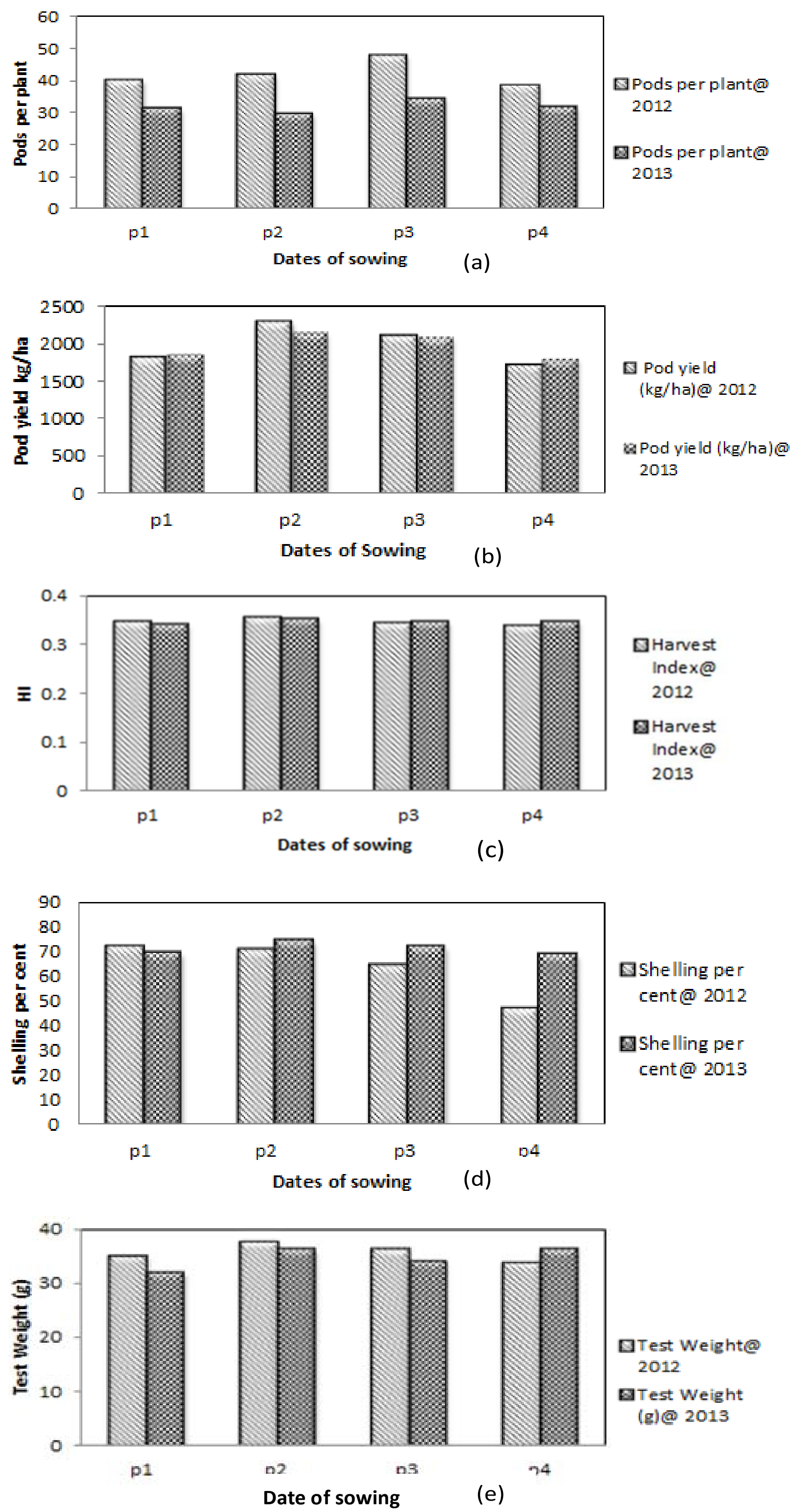

Figure 2. Effect of sowing dates on yield parameters (a) Pods per plant; (b) Pod yield (kg/ha); (c) Harvest Index (d) Shelling per cent and (e) Test weight (g) of Peanut during 2012 and 2013.

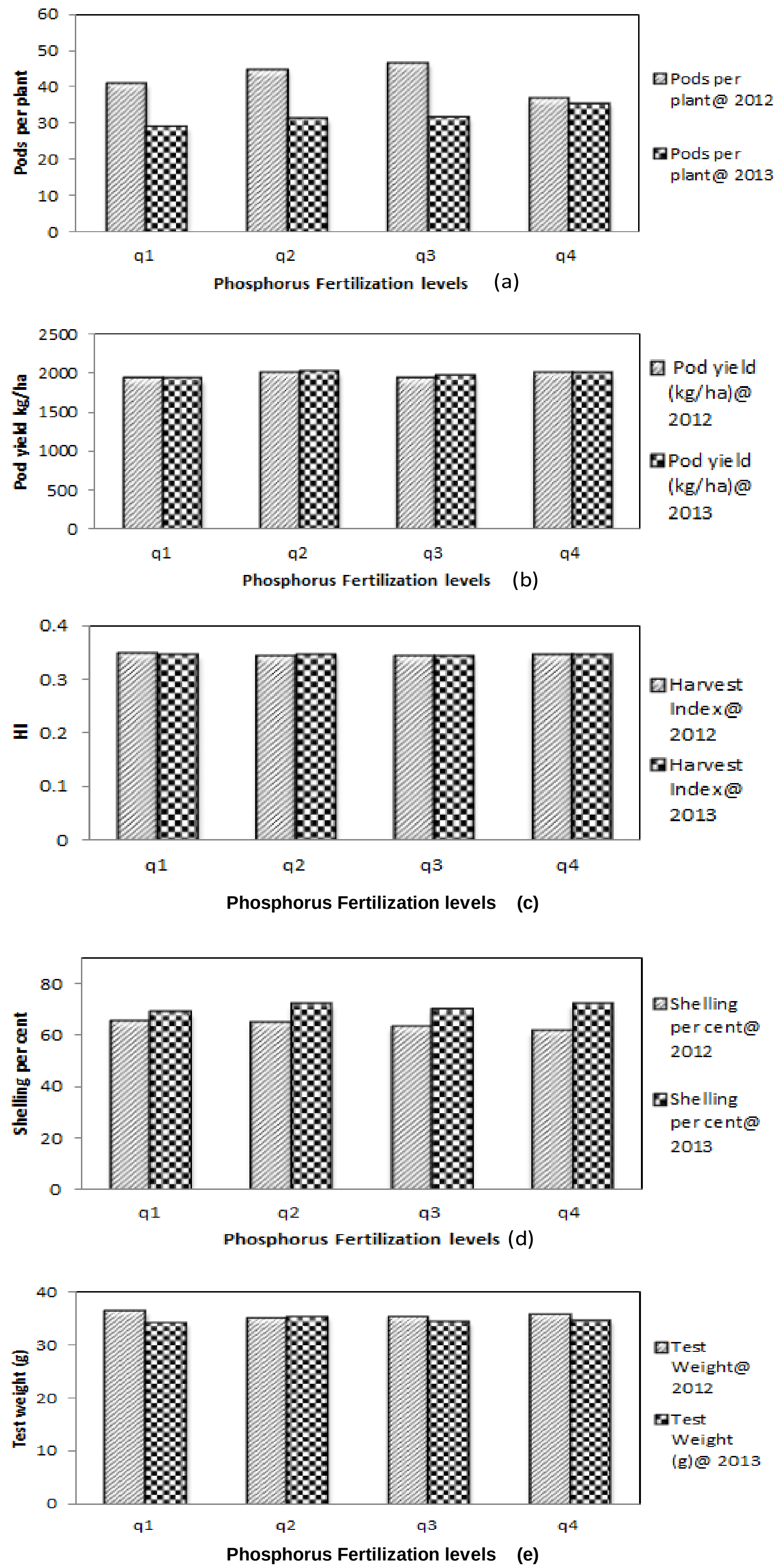

Figure 3. Effect of Phosphorus fertilization levels on yield parameters (a) Number of pods per plant; (b) Pod yield (kg/ha); (c) Harvest Index (d) Shelling per cent and (e) Test weight (g) of Peanut during 2012 and 2013.

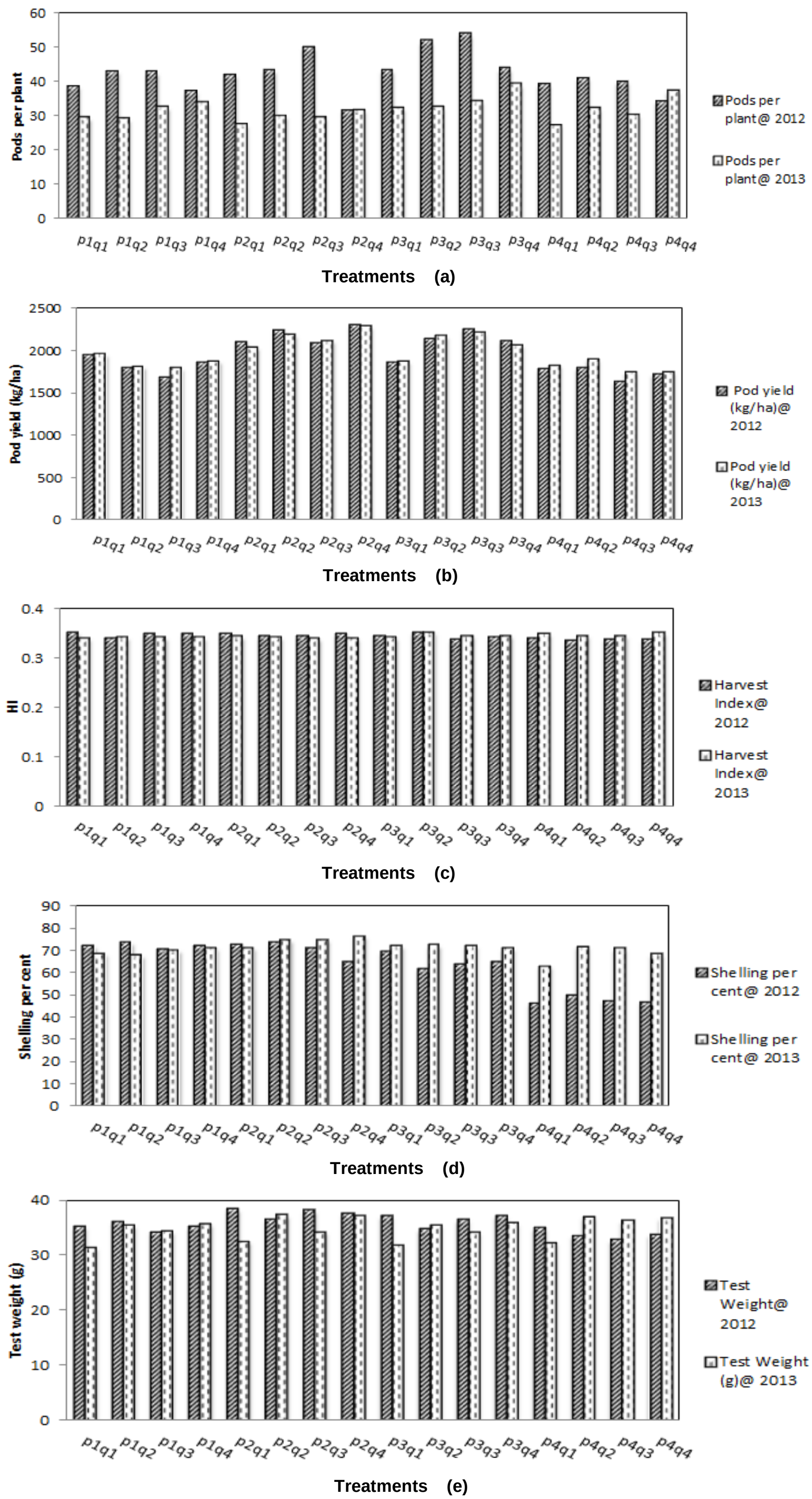

Figure 4. Interaction effect of sowing dates and Phosphorus fertilization levels on yield parameters (a) Number of pods per plant; (b) Pod yield (kg/ha); (c) Harvest Index (d) Shelling per cent and (e) Test weight (g) of Peanut during 2012 and 2013.

year 2012, against (39.04) with p_3q_4 combination of 2013 (Figure 4a). With different level of phosphorus fertilizer and shifting of sowing dates beyond 29th January, shelling percentage decreased during both years experiments (Figure 4d). No significant difference was found in test weight during 2012 and 2013, however, highest test weight (38.34 g) recorded with p_2q_1 combination during 2012 (Figure 4e).

DISCUSSION

Effect of sowing dates, phosphorus fertilization levels on growth parameters

Effect of sowing dates

The results of the study reveal that shifting of sowing dates has significant effect on the growth, yield and yield parameters of peanut. The sowing dates had effect especially on the date emergence, flowering, formation of primary and secondary branches, the maturity dates and yield. The above described study revealed that sowing on 14th and 28th February (p_3 and p_4) did not help in increased in the vegetative growth and development. Late planting exposes plants to warmer weather and longer photoperiods. According to Muldoon (2002), late planted crop has shorter time period for the vegetative growth and formation of pods. This simultaneously reduces the growth rate and the rate of pod formation.

At the same time, soil temperature is also an important parameter for the germination and vegetative growth of crop. Temperature of around 10°C is suitable for the germination of peanut, while the optimum temperature for emergence is between 25 to 30°C (Awal and Ikeda, 2002; Prasad et al., 2006). The soil temperature during the study period was very close to the required minimum temperature which helped in good germination and better vegetative growth of peanut crop during both the seasons.

Effect of phosphorus fertilization levels

Phosphorus fertilizer offers the main nutrient element for the development of root system for legume crop. Balasubramanian et al. (1980) and Sharma and Yaday (1997) reported that phosphorus promotes extensive root development, thereby ensuring a good yield. Phosphorus fertilizer also enhances the supply of other nutrients and water to the growing parts of the plants, resulting in an increased LAI and more dry matter accumulation (Prihar and Tripathi, 1989).

The above described results show that LAI and biomass accumulation increased with increase in the phosphorus fertilization levels (60 to 80 kg P_2O_5 ha^{-1}). This result is supported by the findings of Gobarah et al. (2006) who reported that increased phosphorus fertilization level from 30 to 60 kg P_2O_5 ha^{-1} simultaneously increased vegetative growth, and yield parameters of peanut crop.

Effect of sowing dates, Phosphorus fertilization levels on yield parameters

Sowing dates

The study revealed that shifting of sowing dates up to mid-February helps in increasing yield. Attarde et al. (2001a) had also reported that during summer season shifting of sowing dates from 1st January to 16th and 31st January increases the pod yield. The dry pod yield was the highest for 16th January sown crop (2694 kg ha^{-1}) as compared to 1st January (2537 kg ha^{-1}) and 31st January sown (2340 kg ha^{-1}). Whereas, shelling percent and test weight were significantly higher for 1st January sowing (65.70% and 34.60 g, respectively), as compared to 16th January sowing (64.40% and 34.30 g) and 31st January sowing (61.80% and 32.70 g), respectively. Similar results were also reported by Pathi (1994) and Karanjikar et al. (2004). It was reported that, November is the best period for sowing *rabi* peanut in Southern part of India, whereas, December to end of January is the best period to obtain highest yield in irrigated summer peanut crop. In another study, Ravishankar et al. (2010) reported that early sowing (24th December) gives higher shelling percent. However, delay in sowing beyond 7th January registered a significantly lower shelling percent. Similar finding was reported by Kathirvelan and Kalaiselvan (2007).

The timely sowing also has a significant effect on the pod yield, haulm yield and harvest index. A higher pod yield along with higher haulm yield and harvest index was reported by Ravishankar et al. (2010) in his study. Virender and Kandhola (2007) reported that late sowing lowers the yield due to lower crop water use efficiency in summer peanut.

Phosphorus fertilization levels

The current study revealed that the pod yield is positively influences by the level of phosphorus fertilization. The pod yield of peanut increased with the increase in level of phosphorus fertilizations. The effect of phosphorus fertilization on peanut yield was investigated by several researchers who recommended varied doses of P_2O_5 kg ha^{-1} for raising yield and its attributes, that is, 33 kg (Kumar and Ray, 1997), 40 kg (Dwivedi and Gautam, 1992), 50 kg (Patel et al., 1995), 60 kg (Yakadri et al., 1992) and 114 kg (El-Far and Ramadan, 2000). Similar findings were reported by Kulkarni et al. (1986), Singh et al. (1994), and Thorave and Dhonde (2007).

The reported study also shows that the phosphorus fertilization produces the highest HI (0.18) with 0, 40 and

80 kg P_2O_5 ha^{-1}. This result has been supported by various past studies which show that phosphorus fertilization at 20 kg P_2O_5 ha^{-1} has significant effect on harvest index followed by phosphorus fertilization at 60 kg P_2O_5 ha^{-1} (Nwokwu, 2011).

In case of test weight during 2012, the highest value was obtained for the control treatment (0 kg P_2O_5 ha^{-1}). During 2013, the test weight increased with the increasing level of phosphorus fertilization and produced highest yield with 80 kg P_2O_5 ha^{-1}. On the contrary, Nwokwu (2011) reported that the highest test weight of peanut was found for 20 kg P_2O_5 ha^{-1} followed by 40 kg P_2O_5 ha^{-1}, while the least was obtained for 0 kg P_2O_5 ha^{-1}.

So far the number of pods per plant was concerned, the magnitude increased with the increase in fertilization level during 2012 and 2013, respectively. The highest pods per plant was obtained during 2012 was 46.58 respectively with 80 and 40 kg P_2O_5 ha^{-1}, whereas, for 2013 the highest magnitudes of pods per plant was 35.52 with 80 kg P_2O_5 ha^{-1}. The above mentioned study is supported by a study of Mehta and Ram (1996), in which they registered a significantly higher test weight and higher number of pods per plant with the application of 50 kg P_2O_5 ha^{-1}. An increasing trend in pods yield can also be seen with the increasing fertilization level up to 75 kg P_2O_5 ha^{-1}. Similar investigations have been conducted with application of 60 kg P_2O_5 by Intodia et al. (1998) where significant increase in the number of pods per plant, shelling percentage, pod yield and harvest index of peanut were obtained. In another study conducted by Bhatol et al. (1994) concluded that application of 25 kg P_2O_5 ha^{-1} markedly increased the pod yield. However, the highest yield was obtained for a level of 50 kg P_2O_5 ha^{-1}.

Interaction of sowing date and phosphorus fertilization levels on crop growth and yield parameters of peanut

The combined effect of sowing dates and phosphorus fertilization levels did not have much effect on crop growth and yield parameters (Tables 2 to 3 and Figures 2 to 4). The pod yield during 2012 and 2013 increased with shifting of sowing dates (up to 14th February) and increased fertilization level. Various studies have reported that delay in planting dates reduces vegetative and reproductive growth period and the availability of suitable weather parameters (Canavar and Kaynak, 2010) in term of temperature (maximum and minimum), solar radiation, rainfall etc. during the critical growth period. However, in the reported study, the reduction in yield due to delayed sowing was compensated by the higher level of phosphorus fertilization, as phosphorus is required for better seed development and oil quantity. A similar finding was reported by Canavar and Kaynak (2010) that during late sowing the peanut varieties get stressed because of the short growth cycle and unsuitable growing conditions and ultimately leads to reduction in pod yield.

The combined effect of sowing dates and phosphorus fertilization has no significant effect on the harvested yield and other parameters. All the growth and yield parameters gave the higher yield with shifting of planting time from 14th January up to 14th February.

Conclusion

Appropriate nutrient management as well as sowing time is necessary for attaining good economic return. From the present experiment it is clear that, combination of different sowing dates and phosphorus fertilization have less impact on peanut performance, in terms of pod yield, harvest index, shelling percent, because the soil is rich in phosphorus. So, it may be concluded that, higher peanut yield can be achieved during 2nd fortnight of January to 1st fortnight February sowing date with 40 and 80 kg P_2O_5 ha^{-1} in the sub-humid climate of Eastern India.

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Conflicts of Interest

The authors have not declared any conflict of interest.

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