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EFFECT OF PHOSPHORUS FERTILIZER ON PHOSPHORUS UPTAKE, GROWTH AND YIELD IN SESAME

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ABSTACT

Hasan S, Ahmed S, Zaman MA, Akther S, Hossen MA (2012) Effect of phosphorus fertilizer on phosphorus uptake, growth and yield in sesame. *Int. J. Sustain. Crop Prod.* 7(2), 22-34.

A experiment was conducted at the Agronomy field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the period from March to June, 2003 to study the effects of phosphorus fertilizer application on phosphorus uptake, growth and yield in two sesame varieties viz. BARI Til-2 and BARI Til-3. The phosphorus levels were 0, 30, 60, 90 and 120 kg P_2O_5 ha$^{-1.}$ Plant growth, yield and yield attributes varied significantly due to the variations in phosphorus levels and variety. The highest LAI, CGR, RGR and NAR were recorded in BARI Til-3 at 90 kg P_2O_5 ha^{-1} BARI Til-2 at 60 kg P_2O_5 ha^{-1}. Variety BARI Til-3 responded favorably to phosphorus fertilizer up to 90 kg P_2O_5 ha^{-1} BARI Til-2 responded up to 60 kg P_2O_5 ha^{-1}. Phosphorus fertilizer application resulted in greater phosphorus uptake, higher dry matter accumulation and seed yield in sesame varieties tested. The economic optimum levels of phosphorus for BARI Til-2 and BARI Til-3 were 75 and 85 kg P_2O_5 ha^{-1}, giving yield of 1120 and 1211 kg ha^{-1} respectively.

Key words: *phosphorus, growth, sesame, uptake*

INTRODUCTION

Sesame (*Sesamum indicum* L.) belongs to the family of Pedaliaceae and locally known as 'Til' is one of the oldest cultivated oil crops. It is basically a crop of the tropics and sub-tropics. However, it is one of the important edible oil crops in Bangladesh contributing 10.4% of the countries total oil seed production (Wahhab *et al.* 2002). Oil content of sesame ranges from 34.4 to 59.8 % while protein content ranges from 19-30% (Ashri 1998). India is the world's major sesame producer with a third of the world average and approximately a quarter of the total production (Balasurbramanian and Palaniappan, 1999). In Bangladesh, it ranks third in terms of area and fifth in terms of production among the oil crops (BBS 2003). The national average seed yield is 616 kg ha^{-1} (FAO 1988), which is too low compared to other sesame producing countries of the world. The potential yield (1200-1400 kg ha^{-1}) of sesame is much higher than the average yield. The main reasons for low yield of sesame in Bangladesh are various biotic and a biotic stresses, lack of high yielding varieties and the use of low levels of inputs. Poor photosynthetic efficiency and unfavorable partitioning of the photosynthates to the reproductive plant parts might be another reason for low yield. The yield difference between potential and actual yield indicates wide scope of increasing the productivity of sesame through adoption of high yielding varieties, crop rotation, application of fertilizer especially phosphorus and proper management practices. Higher dry matter production and leaf area expansion are the pre–requisites for greater productivity of the crop plants. Variation in dry matter accumulation and fruit set in different cultivars may be related to factors like crop growth rate, relative growth rate and net assimilation rate. In addition developmental factors affecting the accumulation of dry matter and subsequent partitioning of assimilates are of great importance in determining the final yield (Misa *et al.* 1995). Moreover, grain yield is a function of rate and duration of grain filling (Daynard and Kannenberg, 1976) and the complementary function of vegetative and reproductive growth (Sinha and Khanna, 1975). Phosphorus is a key constituent of ATP and it plays a significant role in the energy transformation in plants (Sankar *et al.* 1984) and also in various physiological processes (Sivasankar *et al.* 1982). It is also essential for energy storage and release in living cells. Phosphorus also plays a vital role in seed formation and its quality improvement. Sesame responds favorably to phosphorus application in a variety of soil. An adequate supply of phosphorus is needed during the growing period of sesame for maximizing yield (Esho and Shekin, 1993). Deshmukh *et al.* (1990) reported that phosphorus plays a beneficial role in sesame growth by promoting root development and thereby ensuring a good seed yield. Ashok *et al.* (1992) also reported that the highest seed yield in sesame was recorded at 75 kg P_2O_5 ha^{-1} along with 120 kg N ha^{-1}, which was statistically at par with an application of 50 kg P_2O_5 ha^{-1}. On the contrary, an inadequate phosphorus supply results in dramatic decreases in plant growth and development. Phosphorus deficiency enhances the accumulation of tri-phosphate in the chloroplast as such and consequently less sucrose is available for the plant growth (Thomson *et al.* 1992). In view of this, the present investigation was undertaken to study the response of sesame to phosphorus fertilizer application in terms of phosphorus uptake, growth and yield.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Agronomy field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during the period from March to June, 2003. The experimental site is

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located at $24^0$09' N Latitude and $90^0$26' E Longitude having an elevation of 8.4 m from the mean sea level and is characterized by sub-tropical climate.

Soil and climate

The soil of the experimental field was silty clay loam of red-brown terrace under salna series. The experimental site is characterized by moderately high temperature and heavy rainfall in summer and moderately low temperature and scanty rainfall in winter. Meteorological data during the crop growing period are shown in Appendix-1. Physical and chemical properties of soils in the experimental field are presented in Table 1.

Table 1. Physical and chemical properties of the experimental soil

Soil properties	Content
Physical	
Texture	Silty clay loam
Sand %	18.00
Silt%	47.00
Clay%	35.00
Chemical	
Total N (%)	0.076
Available P (mg P_2O_5 100^{-1} g soil)	18.00
Exchangeable K (meq 100^{-1} g soil)	0.26
Suphur (ppm)	10.32
P^H	6.4

Treatments

The study comprised the following treatments

A. Variety

The varieties of sesame used in the experiments were:

i. BARI Til-2

ii. BARI Til-3

B. Phosphorus levels

The levels of phosphorus fertilization were:

i) O kg P_2O_5 ha^{-1} ii) 30 kg P_2O_5 ha^{-1}, iii) 60 kg P_2O_5 ha^{-1}, iv) 90 kg P_2O_5 ha^{-1} and v) 120 kg P_2O_5 $ha^{-1.}$

The experiment was laid out in a Randomized Complete Block Design (RCBD) under factorial arrangement with three replications. Unit plot size was 3m × 5m. The adjacent blocks and the adjacent plots were separated from one another by 1.5 m and 1m, respectively. Seeds were treated with vitavax-200 at the rat of 2.5 g kg^{-1} of seeds before sowing. Sowing was done manually in lines on March 13, 2003 Row to row distance was 30cm. The recommended plant distance of 5cm was maintained by thinning plants at 15 DAE. Parameters were analyzed with the help of MSTATC program and mean differences among the treatment were adjusted by using the Least Significant Difference (LSD) test at 5% level of significance

RESULTS AND DISCUSSION

Plant height

The variety and level of phosphorus fertilizer had significant influence on plant height (Table-2). Plant height at maturity varied from 68.5 to 69.8 cm across the varieties. Averaged over phosphorus fertilizers, plant height increased with increasing level of phosphorus fertilizer up to 60 kg P_2O_5 ha^{-1} and then decreased. The interaction effect of variety and phosphorus levels was significant. Generally phosphorus application tended to increase plant height in BARI Til-3 linearly up to 90 kg $P_2O_5ha^{-1}$ but higher levels of phosphorus (beyond 60 kg $P_2O_5ha^{-1}$) fertilizer tended to depress plant height in case of BARI Til-2.

Table 2. Plant height and number of branches $plant^{-1}$ in two sesame varieties as influenced by phosphorus fertilizer application

Phosphorus level (kg $P_2O_5ha^{-1}$)	Plant height (cm)		Number of branches $plant^{-1}$	
	BARI Til-2	BARI Til-3	BARI Til-2	BARI Til-3
0	64.7	66.2	1.4	1.8
30	67.9	67.6	1.8	1.9
60	72.2	70.4	2.1	2.1
90	69.0	73.4	1.9	2.2
120	68.6	71.2	1.8	2.1
LSD (0.05)	2.9		0.2	
CV(%)	7.5		8.4	

Number of branches plant^{-1}

Significant variation in number of branches plant^{-1} in sesame was observed due to the variation in the levels of phosphorus fertilizer applied (Table 2). Varieties and phosphorus fertilizer interaction effects on number of branches plant^{-1} was statistically significant (Table 2). The highest number of branches plant^{-1} was obtained at 60 kg P_2O_5 ha^{-1} in BARI Til-2 and at 90 kg P_2O_5 ha^{-1} in BARI Til-3. It was observed that addition of phosphorus fertilizer beyond 60 kg P_2O_5 ha^{-1} decreased number of branches plant^{-1} in BARI Til-2 while in BARI Til-3, it increased with increasing level of phosphorus up to 90 kg P_2O_5 ha^{-1}. Variety did not show any significant variation in respect of number of branches palnt^{-1}(Table 2).

Leaf area index

The sesame plants in both the varieties responded positively to applied phosphorus fertilizer over the growth period in terms of leaf area expansion (Fig.1). Regardless of treatment variation LAI was the highest at 60 DAE and ranged between 0.74 and 2.52 across the treatments. LAI increased with the increase in age of the plants reaching the peak at 60 DAE and thereafter declined irrespective of treatment differences. The rate of decrease in LAI after attaining the peak was more rapid. LAI decreased at the 60 DAE due to leaf senescence. BARI Til-3 consistently produced more LAI than BARI Til-2. LAI tented to increase with the increase in phosphorus fertilizer application up to 60 kg P_2O_5 ha^{-1} in variety BARI Til-2 and then declined. In contrast, LAI in BARI Til-3 tended to increase with increasing dose of phosphorus fertilizer up to 90 kg P_2O_5 ha^{-1}. Variation between 60 and 90 kg P_2O_5 ha^{-1} were not remarkable in case of LAI at early stage. However, this trend changed subsequently at 40 to 60 days. In general, higher dose of phosphorus (60 to 90 kg ha^{-1}) retained the higher LAI in both the varieties throughout the growth stage than the low levels of phosphorus i.e.0 and 30 kg P_2O_5 ha^{-1}

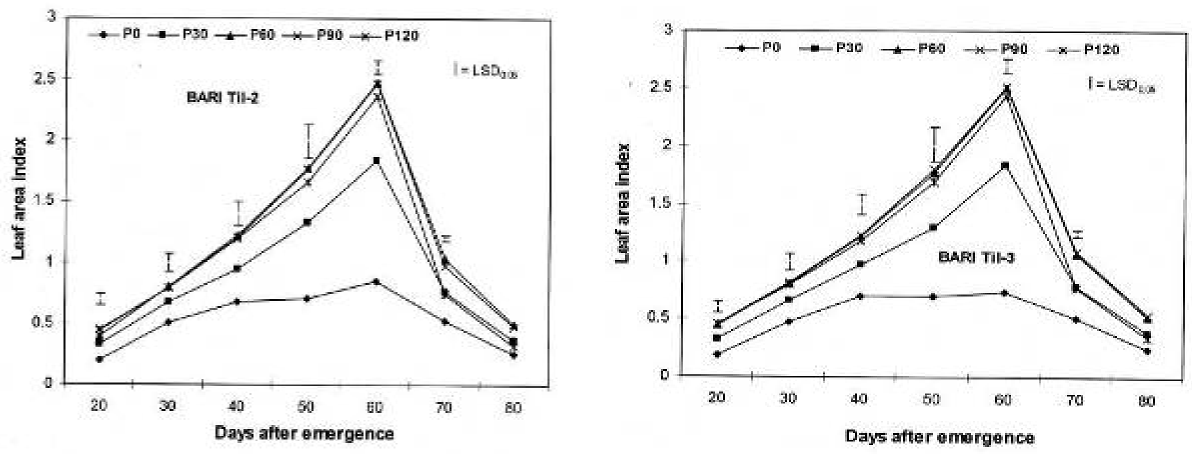

Fig. 1. Leaf area index of sesame (var. BARI Til-2 & BARI Til-3) as influenced by phosphorus fertilization at different growth stages

Total dry matter production

Total dry matter (TDM) in the sum of the dry matter accumulated into various plant components. TDM production indicates the production ability of a crop. A high TDM production is the first pre-requisite for high yield. TDM of the crop depends mainly upon growth rate and the duration of growth (Tanaka 1983). Application of phosphorus fertilizer caused marked variation in TDM and the pattern of dry accumulation in sesame varieties over time (Figures 2a and 2b). Regardless of treatment differences, TDM in sesame varieties increased progressively over time. The rate of increase, however, varied depending on the growth stages. In the present investigation the difference in TDM between the varieties due to phosphorus fertilizer application was less conspicuous in the beginning of the growth cycle but over time the differences widened. A rapid growth rate followed after 35 DAE that continued till maturity irrespective of phosphorus levels. From Figures 2a and 2b, it is evident that a greater portion of TDM was accumulated during the period between 40 and 60 DAE regardless of treatment. Consistently higher TDM was observed in plants treated with 60 kg P_2O_5 ha^{-1} in BARI Til-2 and 90 kg P_2O_5 ha^{-1} in BARI Til-3 at all growth stages. Further increase in phosphorus rate tended to decrease TDM production. On the contrary, the plants grown without phosphorus fertilizer produced the lowest dry matter. It is apparent that the plants grown with low phosphorus fertilizer suffered from nutrient stress resulting in the lowest TDM. The dry matter production was largely a function of photosynthetic surface which was favorably influenced by phosphorus fertilization are root development .Singh and Ahuja (1985) reported that phosphorus fertilizer application increased leaf area and accumulation of more dry matter in groundnut. Leaf area index was closely associated with TDM indicate that 98% of total variation in TDM production would be accounted for by the linear function of LAI (Fig. 2c).

Dry matter partitioning

Dry matter distribution to plant components is an important consideration in achieving desirable yield. The production of economic yield is greatly determined by the production of TDM and its partitioning into reproductive organs (Singh and Yadav, 1989). Dry matter of various plant components at different growth stages varied due to the variation in phosphorus fertilizer levels in both the sesame varieties (Figures. 2a and 2b). Dry matter of leaf increased up to 60 DAE and declined thereafter regardless of treatment. Decline in leaf weight after attaining maximum might be due to translocation of carbohydrates from the leaves to the seed and the onset of leaf senescence. The highest leaf dry weight was found in BARI Til-3 at 90 kg P_2O_5 ha^{-1} and in BARI Til-2 at 60 kg P_2O_5 ha^{-1} throughout out the growth period. Regardless of treatment differences, the variations in leaf dry weight were show at early stage and widened with the advancement of plant age .Similar trend was true for petiole dry weight (Figures. 2a and 2b). However, stem dry weight registered an increasing trend till maturity irrespective of varieties and phosphorus levels. On an average, BARI Til-3 accumulated more dry matter in stem when compared with BARI Til-2. The dry weight of flowers increased linearly in both the varieties up to 50 DAE irrespective of phosphorus levels. However, capsule development proceeded slowly in the beginning but the growth increased sharply later on. The sharp rise in the capsule growth at later stages possibly due to increased translocation of partitioning of photosynthetes from leaves, petioles and stem to the seeds (Bonnett and Incoll, 1992). It is apparent that partitioning of dry matter into capsules in BARI Til-3 was more favorable at a rate of 90 kg P_2O_5 ha^{-1} while in BARI Til-2 it was at 60 kg P_2O_5 ha^{-1} irrespective of growth stages.

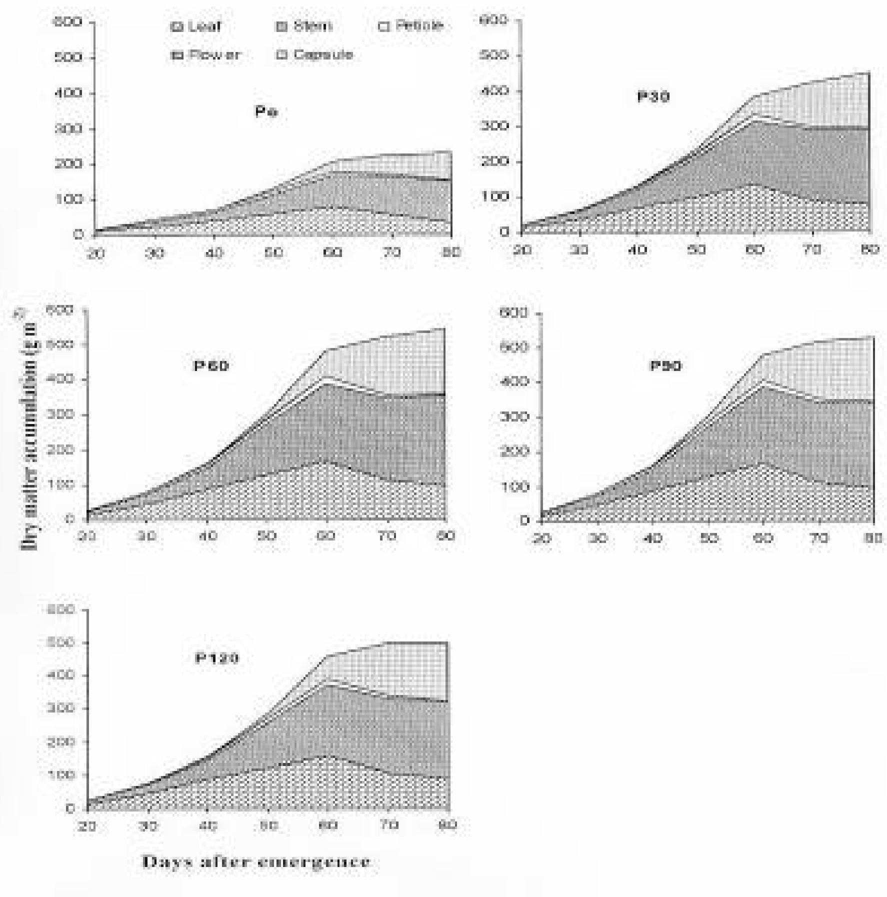

Fig. 2a. Dry matter accumulation in different components of sesame plants (var. BARI Til-2) at different growth stages as influenced by phosphorus fertilizer application

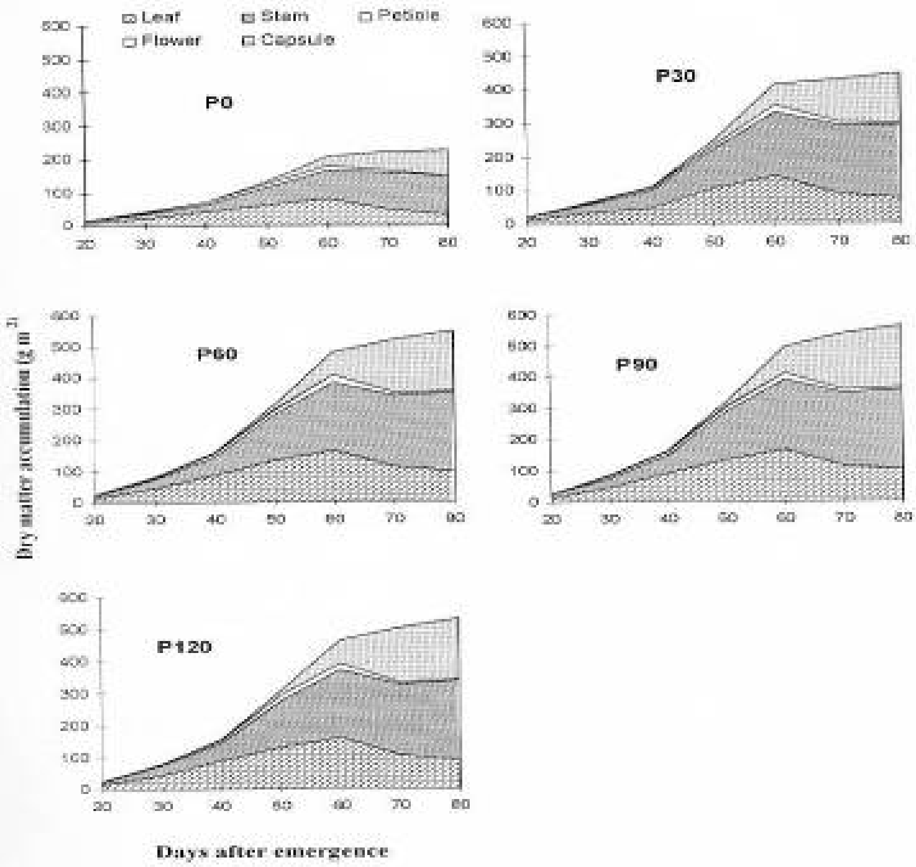

Fig. 2b. Dry matter accumulation in different components of sesame plants (var. BARI Til-3) at different growth stages as influenced by phosphorus fertilizer application

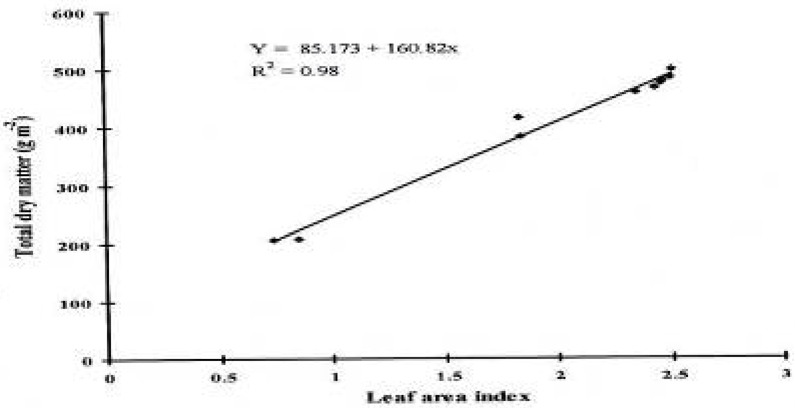

Fig. 2c. Functional relationship between LAI and TDM in sesame plants

Crop growth rate

The crop growth rate (CGR) of sesame in both the varieties (BARI Til-2 and BARI Til-3) was significantly influenced by the phosphorus fertilizer application (Fig. 3). The CGR values increased progressively with time reaching the peak at 60 DAE and thereafter declined sharply till maturity regardless of variety and phosphorus levels. During this period the LAI was also higher. Higher CGR was associated with higher LAI (Khader and Bhargava, 1985). Reduction in growth rate with plant age was probably due to cessation of vegetative growth and leaf senescence. Such information in sesame was cessation of vegetative growth and leaf senescence. Such information in sesame was also reported by Hossain (2001). Treatment variation during the initial and latter growth period was not remarkable but the differences were distinct in the mid growth period. Among the varieties, BARI Til-3 had comparatively higher CGR during the whole growth period. Figure 3 shows that the highest CGR was associated with 60 kg P_2O_5 ha^{-1} in BARI til-2 and decreased as the 90 kg P_2O_5 ha^{-1} was used. Conversely, application of 90 kg P_2O_5 ha^{-1} maintained a higher CGR in BARI Til-3 throughout the growth period. Hossain (2001) also reported that the highest CGR was obtained when the sesame crop was growth with 60 kg P_2O_5 ha^{-1} along with 90 kg N, 60 kg K_2O and 30 kg S ha^{-1}. Plants treated with 0 kg phosphorus produced the lowest CGR irrespective of varieties at all growth stages.

Relative Growth Rate

Relative growth rate (RGR) of sesame varieties as influenced by phosphorus fertilizer application is shown in Fig. 4. Irrespective of treatment, RGR was higher at early stage (20-30 DAE) and showed decreasing trend as crop advanced in age. Similar result was also reported by Hossain (2001) in sesame genotypes. The decrease in RGR might be also due to decrease in NAR.

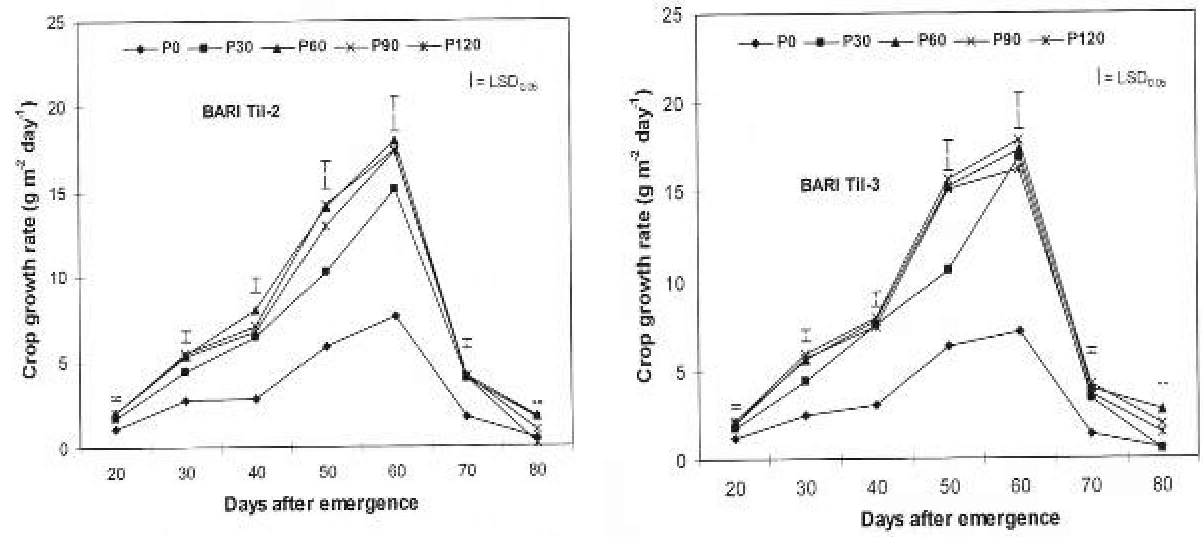

Fig. 3. Crop growth rate of sesame (var. BARI Til-2 and BARI Til-3) at different growth periods as influenced by phosphorus fertilizer

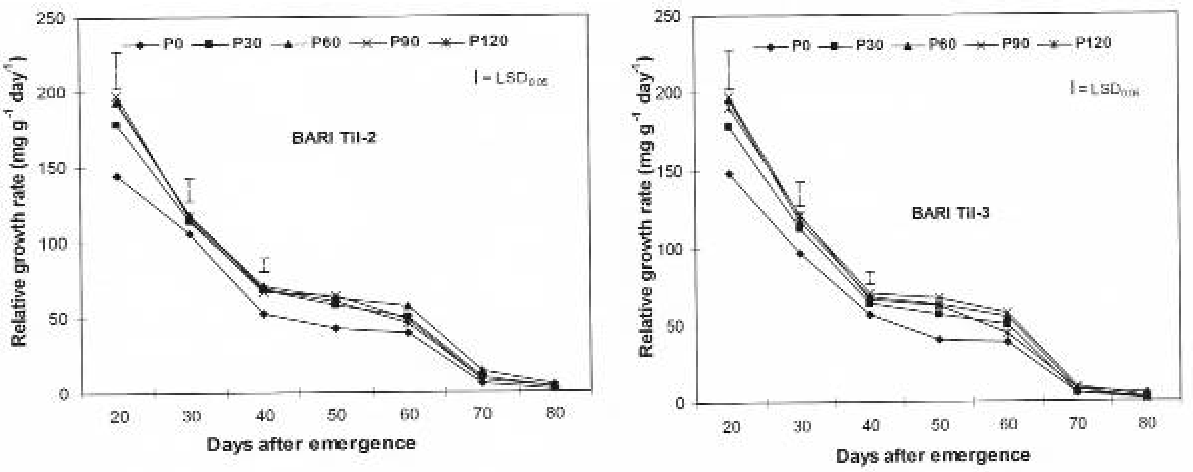

Fig. 4. Relative growth rate of sesame (var. BARI Til-2 and BARI Til-3) at different growth periods as influenced by phosphorus fertilizer

Variation in RCR among the treatments was not apparent in the later growth but the differences were observed in the early stages of crop growth. However, BARI Til-3 maintained relatively higher RGR at 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} at BARI Til-2. The control plants had the lowest RGR irrespective of varieties during the whole growth period.

Net Assimilation Rate

Irrespective of treatments, the NAR or the gain in dry matter weight per unit of leaf area per unit of time showed an increasing trend up to 50 DAE and thereafter declined till maturity (Fig. 5). The increase in NAR in the early growth period was probably due to the increase in leaf area. On the contrary, the decrease in NAR with the advancement of time (after 50 days) might be due mutual shading of leaves that resulted in lower photosynthetic efficiency. Imai *et al.* (1993) also suggested that the NAR tended to decline in the later part of growth mainly because of progressive mutual shading by the increasing of leaf area. However, the NAR was the highest in BARI Til-3 with the increasing levels of phosphorus fertilizer up to 90 kg P_2O_5 ha^{-1} and in BARI til-2 up to 60 kg P_2O_5 ha^{-1}. Plants grown without phosphorus fertilizer had the lowest irrespective of varieties throughout the growth period.

Capsule growth

Capsule growth pattern due to treatments varied significantly depending on growth stages, levels of phosphorus and varieties (Fig. 6). Capsule growth up to 6 days after anthesis was slow in both the varieties.

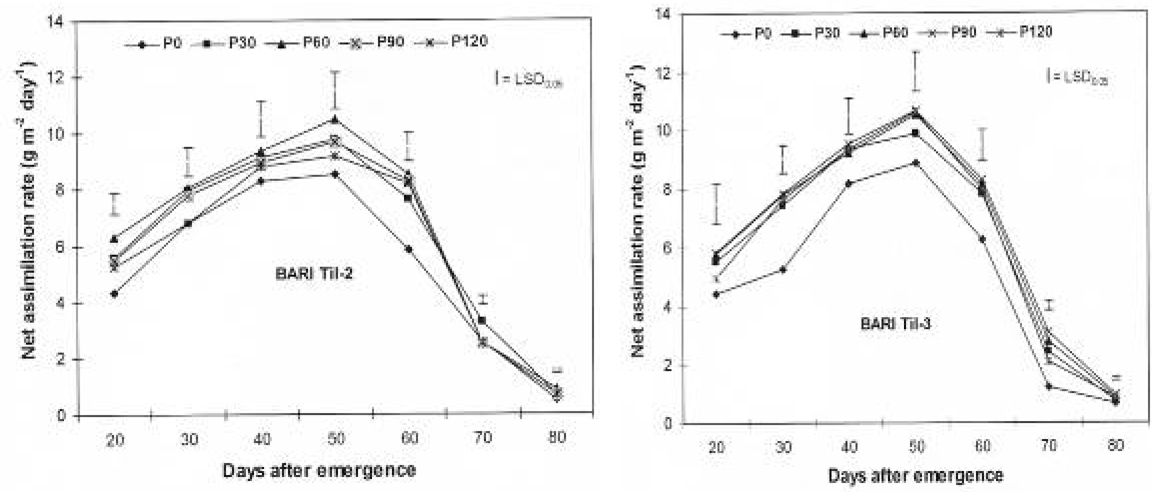

Fig. 5. Net assimilation rate of sesame (var. BARI Til-2 and BARI Til-3) at different growth periods as influenced by phosphorus fertilizer

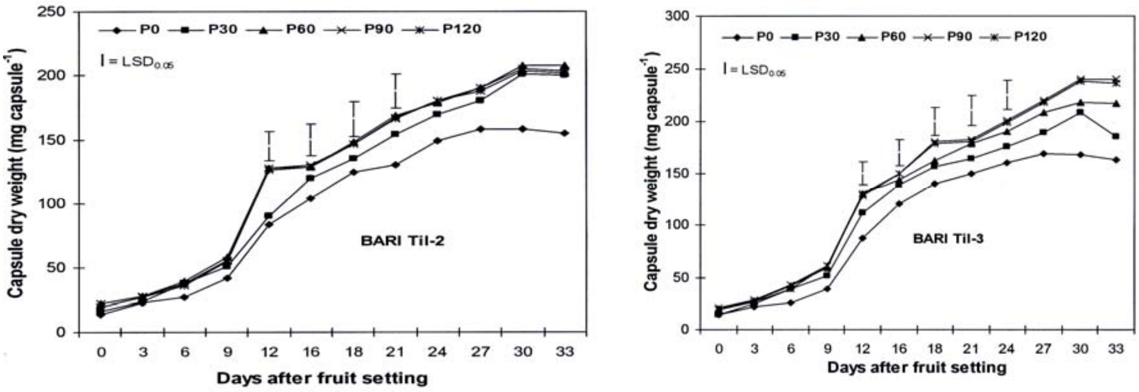

Fig. 6. Capsule growth (mg) in two sesame varieties as influenced by phosphorus fertilizer application

Thereafter, an increasing trend in capsule growth was observed in both the varieties till maturing. However, capsule growth in BARI Til-3 was relatively higher than that in BARI Til-2 throughout the growth period irrespective of phosphorus levels. Plants growth with 90 kg P_2O_5 ha^{-1} had higher capsule growth in BARI Til-3 and with 60 kg P_2O_5 ha^{-1} in BARI Til-2. The capsule growth was high during 21 to 30 days after anthesis and than remained static irrespective treatment. This result indicates that the grain attained physiological maturity at about 30 days after anthesis.

Phosphorus accumulation in plants

Phosphorus content in shoot and seed:

Phosphorus content in shoot and seed of two sesame varieties varied significantly at different stages due to the variation in the amount of phosphorus fertilizer application (Table 3). Phosphorus content was high in shoot at vegetative stage and then decreased over time irrespective of varieties. Reproductive organs, on the other hand, continued accumulating phosphorus till maturity. Decrease in phosphorus content in shoot in the later growth stages might be primarily due to greater translocation of photsynthates to structural and storage organs. Moreover, greater rate of phosphorus absorption occurred than dry matter accumulation during vegetative stage and latter the dry matter accumulation increased more rapidly than absorption of the phosphorus nutrient. This indicated that the higher phosphorus content was needed at early growth, which ultimately translocated to reproductive organ for higher yield. The phosphorus content in shoot and seed was the highest up to the dose of 60 kg P_2O_5 ha^{-1} in BARI Til-2 and up to 90 kg P_2O_5 ha^{-1} in BARI Til-3. The lowest phosphorus content was with 0 kg p_2o_5 ha^{-1}, irrespective of varieties. Phosphorus helps nutrient uptake through root development. At maturity, most phosphorus content was in the seed with increasing levels of phosphorus up to 60-90 kg P_2O_5 ha^{-1} in both the varieties. This suggests that translocation of phosphorus from vegetative tissues to the capsule occurred at seed filling period.

Phosphorus uptake

Uptake of phosphorus by the plant was estimated as dry matter multiplied by phosphorus concentration in dry matter. Phosphorus uptake by shoot, capsule and seed in two sesame varieties differed significantly due to the variation in the amount of phosphorus fertilizer application (Table 4). Response of phosphorus uptake to the applied phosphorus fertilizer varied in two varieties during different growth stages. Increasing rates of applied phosphorus up to 60 kg P_2O_5 ha^{-1} enhanced phosphorus uptake by shoot and seed as well as capsule in the variety BARI Til-2 and up to 90 kg P_2O_5 ha^{-1} in BARI Til-3. Further addition of phosphorus did not increase the uptake of phosphorus in both the varieties.

Table 3. Phosphorus fertilizer effect on phosphorus content in shoot and seed of two sesame varieties at different growth stages

Variety	Phosphorus level (kg $P_2O_5ha^{-1}$)	Phosphorus content (%)				
		Vegetative stage Shoot)	Reproductive stage		Maturity stage	
			Shoot	Capsule	Shoot	Seed
BARI Til-2	0	0.56	0.31	0.19	0.20	0.27
	30	0.65	0.37	0.24	0.25	0.43
	60	0.68	0.40	0.28	0.26	0.49
	90	0.68	0.38	0.25	0.24	0.47
	120	0.67	0.37	0.24	0.24	0.45
BARI-3	0	0.57	0.31	0.20	0.21	0.28
	30	0.62	0.39	0.25	0.26	0.44
	60	0.70	0.42	0.29	0.27	0.51
	90	0.72	0.43	0.30	0.27	0.52
	120	0.68	0.40	0.28	0.27	0.51
LCD (0.05)		0.07	0.03	0.05	0.06	0.09
CV(%)		6.4	7.2	5.4	8.2	9.0

Table 4. Influence of phosphorus fertilizer on phosphorus uptake by shoot and seed in successive growth stages to two sesame varieties

Variety	Phosphorus level (kg P_2O_5 ha^{-1})	Phosphorus uptake (kg ha^{-1})				
		Vegetative stage (Shoot)	Reproductive stage		Maturity stage	
			Shoot	Capsule	Shoot	Seed
BARI Til-2	0	2.36	5.44	0.47	4.60	2.44
	30	4.22	12.13	1.22	11.13	4.25
	60	5.36	16.35	2.07	14.52	5.77
	90	5.42	15.35	1.80	12.78	5.08
	120	5.20	14.46	1.63	11.97	4.73
BARI Til-3	0	2.31	5.49	0.60	4.62	2.79
	30	4.02	13.57	1.62	11.56	4.67
	60	5.69	17.11	2.23	14.82	6.16
	90	6.07	17.59	2.55	15.38	6.52
	120	5.47	15.82	1.99	14.03	5.88
LCD (0.05)		1.8	3.77	74	3.3	1.48
CV(%)		10.2	11.3	8.0	12.0	7.6

Number of capsules plant^{-1}

Application of phosphorus fertilizer exerted significant on the number of capsules plant^{-1}(Table 5). The number of capsules plant^{-1} ranged between 30.4 and 41.1 across phosphorus levels. The highest number of capsules plant^{-1} was obtained with 90 kg P_2O_5 ha^{-1} in BARI Til-3 and with 60 kg P_2O_5 ha^{-1} in BARI Til-2. Further increase in phosphorus fertilizer tended to decrease the number of capsules plant^{-1}in both the varieties tested. Plants grown without or low levels of phosphorus fertilizer had the lowest number of capsules plant^{-1} irrespective of varieties. Phosphorus fertilizer generally enhanced plant growth and higher capsules plant^{-1}. Ali *et al.* (1997) reported that number of capsule plant^{-1} was significantly increased by phosphorus fertilizer application. Irrespective of phosphorus level the number of capsule plant^{-1} varied significantly among the varieties (Table 5). BARI Til-3 produced significantly higher number of capsules plant^{-1} than BARI Til-2.

Number of seeds capsule^{-1}

Plants growth with without phosphorus fertilizer gave the lowest number of seed capsule^{-1}(Table5). The interaction effects of phosphorus levels and variety on the number of seeds capsule^{-1} with increasing levels of phosphorus up to 90 kg P_2O_5 ha^{-1} in BARI til-3 and up to 60 kg P_2O_5 ha^{-1} in BARI Til-2. Similar result was reported by Deshmukh *et al.* (1990) was stated that application of phosphorus fertilizer @ 7.5 kg P_2O_5 ha^{-1} resulted in the highest number of seeds capsule^{-1} in sesame. Irrespective of phosphorus level the varieties differed significantly in producing number of seeds capsule^{-1}. Generally the variety BARI Til-3 had the higher number of seeds capsule^{-1} than BARI Til-2.

Table 5. Yield contributing characters of two sesame varieties as influenced by phosphorus fertilizer application

Phosphorus level (kg P_2O_5 ha^{-1})	Number of capsules plant^{-1}		Number of seeds capsules^{-1}		1000-seed weight (g)	
	BARI Til-2	BARI Til-3	BARI Til-2	BARI Til-3	BARI Til-2	BARI Til-3
0	30.4	32.4	56.3	58.7	2.76	2.80
30	34.4	35.6	60.6	59.9	2.90	2.84
60	38.8	37.8	61.9	62.6	3.04	2.96
90	36.7	40.1	61.4	65.1	3.04	3.07
120	34.9	39.6	60.7	61.8	2.66	2.89
LSD(0.05)	2.9		3.2		0.12	
CV%	4.2		6.3		8.2	

Thousand seed weight

Phosphorus fertilizer effect on 1000- seed weight of sesame was statistically significant (Table-5.). Seed size increased with increase of phosphorus levels up to 90 kg P_2O_5 ha^{-1} and it was statistically identical with 60 kg P_2O_5 ha^{-1}. The variety BARI Til-2 produced the highest 1000-seed weight with 60 kg P_2O_5 ha^{-1}. Likewise increase in 1000-seed weight was observed up to 90 kg P_2O_5 ha^{-1} in the BARI Til-3 and thereafter a reduction in 1000- seed weight. The varieties BARI Til-2 and BARI Til-3 did not differ significantly in terms of 1000-seed weight.

Seed yield ha^{-1}

Seed yield of sesame is the function of number of plants per unit area, number of capsules plant^{-1}, number of seeds capsule^{-1} and seed size or 1000- seed weight. The seed yield of sesame varied significantly due to phosphorus levels (Table 6). Phosphorus fertilizer generally increased seed yield over control. There was almost a linear increase in seed yield with the increase in phosphorus fertilizer up to 60 kg P_2O_5 ha^{-1} in BARI Til-2 and up to 90 kg P_2O_5 ha^{-1} in BARI Til-3 and further increase in phosphorus levels decreased the yield. Seed yield ha^{-1} showed significant variations among the varieties (Table 6). The highest seed yield ha^{-1} was obtained from variety BARI Til-3 that was significantly different from BARI Til-2. Higher seed yield in variety BARI Til-3 came mainly from the number of capsules plant^{-1} and 1000 –seed weight. There was a liner relationship between the capsules plant^{-1} and seed yield^{-1} (R^2=0.90). This indicates that 90% of the total variation in seed yield could be explained by the variation in number of capsules plant^{-1}(Fig. 7). There was also a linear relationship between seed size and seed yield (Fig. 8). This result showed that seed yield of sesame increased with the increase in phosphorus level up to a certain limit. Irrespective of varieties, the lowest yield was obtained from the plants grown without phosphorus or low level of phosphorus fertilizer. The low yield would have been due to the lower number of capsules plant^{-1}, 1000 – seed weight and less efficient in utilizing the fraction of dry matter into the economic component (Kumari *et al.* 1988).

Table 6. Yield, harvest index and oil content in two sesame varieties as influenced by phosphorus fertilizer application

Phosphorus level (kg P_2O_5 ha^{-1})	Yield (kg ha^{-1})		Harvest index		Oil content in seed (%)	
	BARI Til-2	BARI Til-3	BARI Til-2	BARI Til-3	BARI Til-2	BARI Til-3
0	896.4	996.5	0.28	0.31	39.7	39.8
30	985.2	1055.7	0.29	0.33	40.1	40.8
60	1171.0	1200.2	0.34	0.34	41.5	41.5
90	1076.4	1244.2	0.31	0.36	42.3	42.8
120	1047.6	1150.2	0.30	0.33	39.0	39.2
LSD (0.05)	45.8		NS		0.9	
CV (%)	9.4		6.2		10.8	

NS = Not significant

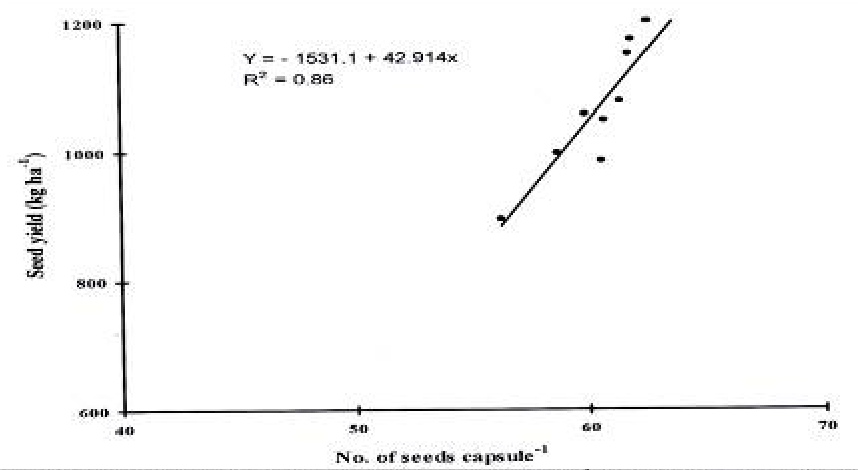

Fig. 7. Functional relationship between seeds capsule^{-1} and seed yield in sesame

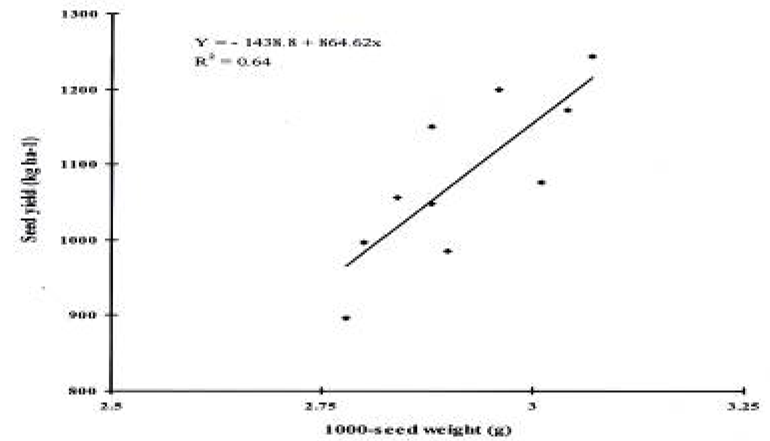

Fig. 8. Functional relationship between 1000-seed weight and seed yield in sesame

There existed a linear relationship between total dry matter (TDM) and seed yield of sesame (Fig. 9). Seed yield was closely associated with TDM (R^2=0.67). It indicates that 67% of total variation in yield would be explained by the increase in TDM. There was also a positively linear relationship between the phosphorus uptake and seed yield in sesame (Fig. 10). The functional relationship suggests that over 77% of the variation in yield can be attributed to the increase in phosphorus uptake.

The relationship between phosphorus levels and seed yield worked out for each variety was (Fig. 11) as follows.
$Y= 882.54 + 6.240\ p-0.041P^2$, $R^2= 0.82$(for BARI Til-2)
$Y= 972.60 +5.513p-0.032P^2$, $R^2 = 0.88$ (for BARI Til-3)

The value R^2 (0.82 to 0.88) indicates that 82 and 88% of the total variation in seed yield in sesame varieties could be explained by the variation in phosphorus fertilizer. From these equations, the maximum estimated yield of BARI Til-2 and BARI Til-3 were 1120 and 1211 kg ha^{-1} at 76 and 86 kg P_2O_5 ha^{-1}, respectively. The optimum levels of phosphorus for BARI Til-2 and BARI Til-3 may be 76 and 86 kg P_2O_5 ha^{-1} for yield target of 1120 and 1211 kg ha^{-1}, respectively.

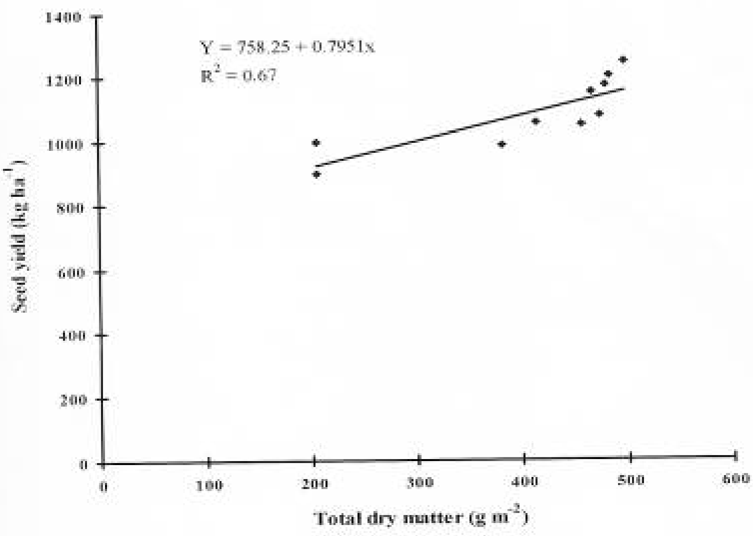

Fig. 9. Functional relationship between TDM and seed yield in sesame

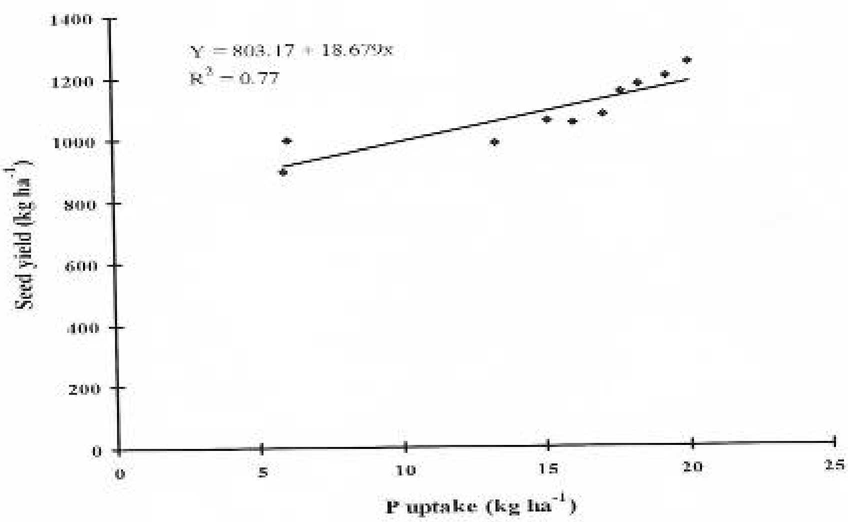

Fig. 10. Functional relationship between P uptake and seed yield in sesame

Harvest index

Harvest index (HI), the proportion of seeds to total above ground biomass, was generally low which varied between 0.28 and 0.36 across the treatments (Table 6). BARI Til-3 had higher harvest index than BARI Til-2 HI was higher in BARI Til-3 indicating favorable partitioning of the dry matter towards the production of economic yield in this variety. Application of phosphorus fertilizer also exerted significant influence on HI (Table 6). Plant receiving 60 and 90 had the highest HI which was statistically different from the rest of phosphorus levels. Higher HI with 60-90 kg $p_2o_5ha^{-1}$ was possibly due to increased phosphorus uptake and dry matter accumulation resulting from increased mobilization of phosphorus towards seed. Further increase in phosphorus educed HI. Plants grown with lowest (30 kg ha^{-1}) or without phosphorus had the lowest HI.

Oil content in seed

Phosphorus fertilizer had significant effect on oil content in sesame (Table 6). Increase in phosphorus levels up to 90 kg ha-^{1} tended to increase oil content in sesame seeds and then decreased .phosphorus rates and varieties interaction on the oil content was also statistically significant (Table 6). The interaction effect revealed that the highest percentage of oil was obtained with 90 kg p_2o_5 ha^{-1} irrespective of varieties. The results are in accordance with those observed by Jana et al. (1991) and Bhatol *et al.*(1994) they reported increase in P level from 0 to 70 kg ha^{-1} increased oil content in groundnut.

CONCLUSION

A Field experiment was conducted at the Bangladesh Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during the period from March to June, 2003 to determine the influence of different levels of phosphorus fertilizer on phosphorus uptake, growth and yield performance of sesame, Variety BARI Til-3 performed relatively better than BARI Til-2 in terms of p uptake, biomass production and seed yield. Leaf area index (LAI) increased sharply after emergence reaching the peak at 60 DAE and thereafter decreased regardless of treatments. Total dry matter (TDM) also differed appreciable due to phosphorus fertilizer and variety. Higher rate of dry matter accumulation was observed during 40-60 DAE. LAI and TDM increased with the increase in phosphorus levels up to 90 kg P_2O_5 ha^{-1}in BARI Til-3 and a declining trend was observed beyond 60 kg P_2O_5 ha^{-1} in BARI Til-2. Crop growth rate (CGR) increased steadily reaching the peak at 60 DAE and thereafter decreased sharply irrespective of the variety and phosphorus levels. Application of 60 kg P_2O_5 ha^{-1}caused higher CGR in VARI Til-2 and 90kg P_2O_5 ha^{-1}in BARI Til-3 in all growth periods. Variety BARI Til-3 responded favorably to phosphorus fertilization up to 90 kg P_2O_5 $ha^{-1}$and it was statistically identical with 60 kg ha^{-1} in terms of yield and yield components while variety BARI Til-2 responded up to 60 kg P_2O_5 ha^{-1}. Increase in phosphorus rate increased HI linearly up to 90 kg ha^{-1} in BARI Til-3 and 60 kg P_2O_5 ha^{-1} in BARI Til-2 and further increase in phosphorus fertilizer did not enhance the HI. However, response of seed yield of sesame varieties to added phosphorus fertilizer was quadratic. The optimum levels of phosphorus for BARI Til-2 and BARI Til-3 might be 75and 85 kg P_2O_5 ha^{-1}, respectively for a yield target of 1120 and 1211 kg ha^{-1}.

On the basis of the results of the experiment the following conclusion can be made:

1. The growth of sesame plants significantly increased with the increase in phosphorus fertilizer level up to 60 kg P_2O_5 ha^{-1} in BARI Til-2 and up to 90 kg P_2O_5 ha^{-1}in BARI Til-3.
2. Both phosphorus content in plant tissues and phosphorus uptake by sesame plants at different growth stages increased with the increase in phosphorus fertilizer level up to 60 kg P_2O_5 ha^{-1} in BARI Til-2 and up to 90 kg P_2O_5 ha^{-1}in BARI Til-3
3. Yield and yield attributes in sesame significantly increased with the increase in phosphorus fertilizer application up to 60kg P_2O_5 ha^{-1} in BARI Til-2 and up to 90 kg P_2O_5 ha^{-1} in BARI Til-3.
4. Oil content in sesame seed significantly increased with the increase phosphorus level up to 90 kg P_2O_5 ha^{-1} in both the varieties, BARI Til-2 and BARI Til-3 and Among the varieties, BARI Til-3 performed better than BARI Til-2 in terms of crop growth, phosphorus.

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