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ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
Lam, Guntur - 522 034

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COMPARISION OF RESPONSE OF GROUNDNUT GENOTYPES AT DIFFERENT PHOSPHORUS LEVELS

AJAY B.C*, SINGH A.L., BERA S.K., NARENDRA KUMAR, DAGLA M.C and K.C. NATARAJ

Directorate of Groundnut Research, Junagadh, Gujarat – 362 001

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ABSTRACT

Low phosphorus (P) availability in soil is one of the limiting factors affecting groundnut productivity by reducing leaf area and dry weight. This study evaluated groundnut genotypes for their ability to thrive and produce on calcareous soils with low phosphorus availability. Assessment of shoot biomass, root biomass, shoot P-concentration, kernel P-concentration, P-accumulation and yield were completed using three phosphorus levels and 23 groundnut genotypes. Study was conducted with three phosphorus levels namely no (P_0), normal P (P_{50}) and high P (P_{100}) as the main factor with genotypes as second factor arranged in a factorial completely randomized design. Significant genotypic differences were observed for the characters studied. Shoot P-concentration and accumulation increased with increase in phosphorus levels, whereas, root biomass and kernel P-concentration decreased with increase in phosphorus levels. There was varying response of genotypes for yield, kernel P-concentration and accumulation, shoot P-concentration and accumulation, biomass and harvest index. In addition, genotypes ICG-221, GG-5, TG-37A and FeESG-10 were designated as 'high yielder–non-responsive', whereas, genotypes NRCG-15049, TPG-41, GPBD-4 and NRCG-3498 were identified as 'low yielder - responsive'. These genotypes can be used in breeding programs to develop 'high-yielder– responsive' genotypes.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop grown in an area of about 5.3 mha in India with the production of about 9.2 m ton (FAO, 2017). It is an important source of protein for resource-poor households. Though number of high yielding cultivars have been released, productivity on small fields remains low. Inadequate application and low availability of native phosphorus (P) in the soil limit the groundnut productivity in semi-arid tropics. Groundnut being a leguminous crop most of its nitrogen demand is met by biological N_2 fixation. Insufficient P availability can lead to reduced N_2 fixation *vis-a-vis* N_2 deficiency besides direct effects on crop growth and yield (Brgaz *et al.,* 2012).

Phosphorus deficiency can be overcome by corrective soil fertility amendment strategies such as application of phosphatic fertilizers. However, it is difficult for farmers in developing countries to undertake soil fertility amendments. Response to P application depends on ability of a genotype to take-up P from soil (uptake efficiency) or use of absorbed P for producing biomass yield (utilisation efficiency). Hence, there is a need for varieties capable of acquiring phosphorus from limiting soil environments. Genotypic differences have been reported in groundnut for its ability to acquire phosphorus from limiting environments (Ajay *et al.*, 2017). Therefore, objective of the study was to determine the effect of phosphorus levels on plant growth and to identify a suitable selection criterion under low-P availability.

MATERIAL AND METHODS

Field screening was conducted during 2012 at ICAR-Directorate of Groundnut Research, Junagadh, in a medium black calcareous (17% $CaCO_3$) clayey, Vertic Ustochrept soil having

***Corresponding author E-mail i.d:** ajaygpb@yahoo.co.in

moderate available phosphorus (15 kg ha^{-1} P), 7.5 pH, 0.7% organic C,268 kg ha^{-1} N, 300 – 400 kg ha^{-1} K, 5 kg ha^{-1} available S and 1.6 kg ha^{-1}, 15 kg ha^{-1} and 0.78 kg ha^{-1} DTPA extractable Fe, Mn, and Zn, respectively. Experiment was laid out in split-plot design with P levels as main plot and genotypes in sub plot with two replications. Treatments involving three levels of P application *i.e.* no-P (P_0, 0 kg P_2O_5/ha) medium-P (P_{50}, 50kg P_2O_5/ha) and high-P (P_{100}, 100kg P_2O_5/ha) as di-ammonium phosphate were included. Nitrogen (as urea) and potash (as murate of potash) were applied at 50 kg N/ha and 60 kg K_2O/ha equally for all the treatments. The recommended crop management practices were adopted for raising a healthy crop. Crop was harvested at maturity dried under sun for a week and yield related traits were recorded. Plant and kernel samples were digested using di-acid mixture of nitric acid and perchloric acid in the ratio of 2: 1 and P-concentrations ([P]; mg/g) was estimated (Fiske and Subbarao, 1925). Phosphorus harvest index (PHI) was calculated as PHI (%) = (P uptake in kernels/ total P uptake) x 100 (Yaseen and Malhi, 2009). Means were separated using least significant difference (LSD) test at 95% significance level.

RESULTS AND DISCUSSION

Analysis of variance indicated that significant effect of phosphorus levels on RDW, SHP, KYP, SP, SPU, KP, KPU and PHI. Similarly, genotypic effect was highly significant for all variables tested and phosphorus by genotypes interaction was significant for most of the variables except HSM and SHP (Table 1). Results agree with earlier studies (Singh *et al*, 2015) corroborating the hypothesis that groundnut differs in their ability to thrive in P limiting environments. The effect of phosphorus levels was highly significant ($P<0.05$) on root biomass and it was higher at P_0 and on-par at P_{50} and P_{100} (Table 2). RDW ranged from 0.44 (ICG-4751) to 1.30 g/plant (GPBD-4). RDW decreased with the increase in phosphorus levels for STARR, GG5, NRCG-15049, SP-250A, VRI-3 and B-95 upto P_{100} (Fig. 1). RDW decreased for genotypes Girnar-3, ICG-221, TG-37A, TPG-41, FeESG-8, NRCG-162 and GG-20 upto P_{50} and increased at P_{100}. However, root biomass obtained from soil culture may not be suitable to use as selection criteria as recovery of whole root system might have been incomplete (Hinsinger, 2001).

There was no significant difference in SDW between P levels, however, it increased when P levels were either decreased (P_0) or increased (P_{100}). SDW ranged from 11.92 (ICG-4751) to 22.01 g/plant (SP-250A) (Table 2). SDW decreased at P_{50} and increased at P_{100} for CHICO, ICGV-86590, JL-24, TG-37A, FeESG-10, NRCG-1308 and VRI-3; increased at P_{50} and decreased at P_{100} for ICG-1955, STARR, GG5, B-95 and GG-20; increased up to P_{100} among genotypes NRCG-15049, TPG-41, GPBD-4, NRCG-3498 and GG-7; decreased up to P_{100} for genotypes ICG-221, FeESG-8, SP-250A and NRCG-162 (Fig. 2). The genotypes that have high mean shoot biomass at deficient phosphorus level may be termed as efficient probably because soil P is somehow sufficient for them or they invest large part of the assimilate to the roots for enhanced soil exploration to support shoot biomass production (Mourice and Tryphone, 2012). In the study, under P_0, genotypes ICGV-86590 and SP-250A had high shoot biomass till harvest and may be considered as efficient which is also in agreement with our earlier studies (Ajay *et al*., 2013; Singh *et al*., 2015). However, there was no significant difference between different P levels for shoot biomass which may be due to the fact that calcareous nature of the soil may fix much of the applied phosphorus thus rendering it unavailable for the plants. Second reason could be the production of more photosynthates than could be utilized for growth and low cytosolic Pi favours starch versus sucrose synthesis in vivo by diminishing the export of triose phosphate out of the chloroplast via the

phosphate translocation (Cho *et al*., 2015*).* Hence, under P limitations, photosynthates are not transported and starch gets accumulated in shoots (Hammond and White, 2008) due to reduction in sink strength. Starch accumulation is responsible for gain in dry matter in shoots under P_0 which increases shoot weight, thus, making P_0 on par with P_{50} and P_{100}.

HSM ranged from 16.49 (NRCG-162) to 44.77 g (B-95). Though HSM did not differ between P levels, it increased with increase in P levels in ICG-221, TPG-41, GPBD-4, VRI-3 and GG-7; decreased with increase in P application in STARR, NRCG-1308 and B-95; increased at P_{50} and decreased at P_{100} among genotypes ICGV-86590, JL-24, GG5, NRCG-15049, TG-37A, SP-250A, NRCG-162 and GG-20; and decreased at P_{50} and increased at P_{100} in Girnar-3 ICG-4751, FeESG-8, FeESG-10 and NRCG-3498 (Table 2). Likewise, SHP was highest at P_{50} and on par at P_0 and P_{100} ranged from 57.90 (SP-250A) to 77.04% (NRCG-15049). In general, SHP increased at P_{50} and decreased at P_{100} for genotypes CHICO, ICG-4751, ICGV-86590, JL-24, STARR, NRCG-15049, TPG-41, GPBD-4, B-95, NRCG-162 and GG-7; increased upto P_{100} in genotypes ICG-1955, ICG-221, FeESG-8 and FeESG-10 and decreased with increase in P levels among genotypes TG-37A, NRCG-1308, NRCG-3498, SP-250A, VRI-3 and GG-20 (Table 2).

Shoot P-concentration (SP) was low in P_0 and on par at P_{50} and P_{100} and it was highly variable among the genotypes ranging from 1.42 (GG-20) to 2.27 g/100g (NRCG-162) (Table 2). There was increase in SP among genotypes Girnar-3, CHICO, ICG-1955, NRCG-15049, TG-37A, FeESG-10, NRCG-1308, B-95 and GG-7 with increase in P levels (Fig. 3) but genotypes ICGV-86590, TPG-41, NRCG-3498 and SP-250A showed reductions in SP. However, there was an increase in SP upto P_{50} among genotypes JL-24, STARR, GG5, GPBD-4, FeESG-8 and NRCG-162 and started decreasing at $P_{100,}$ whereas, genotypes ICG-4751, ICG-221, VRI-3 and GG-20 had reduced SP at P_{50} which still increased at P_{100}.

Shoot P-accumulation (SPU) was high at P_{100} and on par at P_0 and P_{50} and it ranged from 18.04 (ICG-4751) to 45.09 mg/plant (GG-5) (Table 2). There was an increase in SPU with increase in P levels among genotypes ICG-4751, NRCG-15049, TG-37A, B-95 and GG-7, whereas, genotypes ICG-221, SP-250A and NRCG-162 showed reduction in SPU (Fig. 4). However, there was increase in SPU upto P_{50} among genotypes Girnar-3, ICG-1955, STARR, GG5, FeESG-8 and GG-20 and started decreasing at P_{100} whereas genotypes CHICO, ICGV-86590, ICG-221, FeESG-10, NRCG-1308 and NRCG-3498 showed decrease in SPU at P_{50} which still increased at P_{100}.

Kernel P concentration (KP) was high at P_0 and was on-par when P application was increased. KP ranged from 21.82 (NRCG-1308) to 44.04 g/100g (GPBD-4) (Table 2). There was increase in KP with increase in P levels among genotypes ICG-221, TG-37A, VRI-3 and B-95, whereas, it was low in genotypes ICGV-86590, STARR, GG5, NRCG-15049, NRCG-162 and GG-20 (Fig. 5). However, there was increase in KP upto P_{50} among genotypes Girnar-3, ICG-4751, ICG-221, TPG-41, FeESG-8, SP-250A and GG-7 and started decreasing beyond that level whereas genotypes GPBD-4, FeESG-10 and NRCG-3498 showed decrease in KP at P_{50} which still increased at P_{100}.

Kernel P-accumulation (KPU) was on par at P_0 and P_{100} for all genotypes and it ranged from 3.46 mg/plant (NRCG-162) to 15.51 mg/plant (GG-7) (Table 2). KPU increased with increase in P application among genotypes TPG-41, GPBD-4, NRCG-3498 and VRI-3 and decreased in genotypes ICG-221, STARR, FeESG-8, NRCG-1308 and NRCG-162 (Fig. 6). In some of the genotypes such as ICG-4751, ICGV-86590, JL-24, GG5, B-95 and GG-7 KPU

increased upto P_{50} and then decreased at $P_{100,}$ whereas, genotypes CHICO, ICG-1955, NRCG-15049, TG-37A and FeESG-10 showed decrease in KPU at P_{50} and increased at P_{100}.

Kernel yield plant^{-1} (KYP) was high at P_{50} and reduced at other P levels (P_0 and P_{100}) (Table 2) and it ranged from 0.78 g/plant (NRCG-162) to 3.56 g/plant (GG-7). Generally, KYP increased upto P_{50} and reduced at P_{100} in Girnar-3, ICG-4751, ICGV-86590, JL-24, SP-250A, VRI-3, B-95, GG-7 and GG-20; decreased at P_{50} and increased at P_{100} in genotypes CHICO, ICG-1955, FeESG-8, FeESG-10 and NRCG-1308; decreased upto P_{100} in genotypes ICG-221, STARR, GG5, NRCG-3498 and NRCG-162; and increased with increase in P application among genotypes NRCG-15049, TPG-41 and GPBD-4 (Fig. 7). PHI was high at P_{50} and was on-par when P application was increased or decreased. Similarly, PHI varied significantly among the genotypes ranging from 9.63 (NRCG-162) to 38.04% (NRCG-1308) (Table 2). In general PHI decreased when P application was either increased or decreased for all the genotypes. In most of the genotypes, PHI increased upto P_{50} and then started decreasing. In few genotypes such as ICG-1955, NRCG-15049, GPBD-4, and FeESG-10 showed decrease in PHI at P_{50} which still increased at P_{100} (Fig. 8). However, in genotypes ICG-221, GG5, TG-37A and FeESG-8 PHI decreased with increase in P application upto P_{100} and genotype TPG-41 showed increase in PHI with increase in P application upto P_{100}. In genotypes Girnar-3, STARR and NRCG-162 PHI was on-par at P_0 and P_{100}.

Kernel yield increased with the application of P upto P_{50} and excess of application reduced yields. Yield reduction under P_{100} is due to antagonistic reaction with other cationic mineral elements such as copper (Cu) iron (Fe) manganese (Mn) and zinc (Zn) (Hopkins and Ellsworth, 2003). Significant interaction between genotype and P level for kernel yields in the study corroborates with earlier studies (Singh *et al*., 2015). However, this

Table 1. ANOVA for variables measured from 23 groundnut genotypes

Variable	P	G	P x G
RDW	**	**	**
SDW	NS	**	**
HSM	NS	**	NS
SHP	*	**	NS
KYP	**	**	**
SP	**	**	**
SPU	*	**	**
KP	**	**	**
KPU	**	**	**
PHI	**	**	**

RDW = Root dry weight (g); SDW: Shoot dry weight (g) ; HSM: Hundred seed mass (g); SHP: Shelling percentage (%) ; KYP: Kernel yield per plant (g/plant); SP: shoot P- concentration (g/100g); SPU: Shoot P-accumulation (mg/plant) ; KP: Kernel P- concentration (g/100g); KPU: Kernel P- accumulation (mg/plant); PHI: P- harvest index

Table 2. Effect of P levels on yield related characters of 23 groundnut genotypes

Genotype	RDW	SDW	SP	SPU	KP	KPU	PHI	HSM	SHP	KYP
1.GG-7	0.77 c-f	15.39 g-k	1.77 b-h	32.23 b-e	27.36 b-d	15.51 a	36.54 a-b	43.07 a-b	70.58 a-c	3.56 a
2.FeESG-10	0.61 f-j	20.46 a-c	2.23 a	38.04 a-c	45.71 a	14.42 a-c	23.79 d-f	25.74 h-k	64.78 a-c	3.51 a
3.GG-5	0.80 c-e	19.01 b-e	1.69 c-h	45.09 a	32.25 b	14.58 a-b	30.97 a-d	37.36 b-d	73.17 a-b	3.34 a-b
4.TG-37A	0.76 c-f	14.83 g-k	1.62 d-h	26.79 c-f	24.08 c-d	13.06 a-d	35.50 a-c	35.05 c-e	67.23 a-c	3.26 a-c
5.TPG-41	0.84 c-d	14.93 g-k	1.47 g-h	24.81 d-f	21.86 d	13.32 a-d	37.40 a-b	38.48 a-c	64.95 a-c	3.10 a-d
6.VRI-3	0.56 h-j	16.46 f-i	1.82 b-g	36.71 a-d	29.77 b-c	14.77 a-b	31.10 a-d	27.49 g-k	70.74 a-c	2.99 a-d
7.ICG-221	0.74 d-g	16.03 f-j	1.53 f-h	26.59 c-f	24.40 c-d	12.57 a-d	33.37 a-d	27.16 g-k	71.96 a-c	2.97 a-e
8.Girnar-3	0.57 g-j	13.88 i-l	2.05 a-b	27.70 c-f	28.29 b-d	12.34 a-d	30.04 a-d	28.25 f-i	71.28 a-c	2.94 a-e
9.NRCG-1308	0.69 d-h	13.61 j-l	1.60 e-h	28.53 c-f	21.82 d	13.51 a-c	38.04 a	38.42 a-c	72.09 a-c	2.89 a-f
10.SP-250A	0.80 c-e	22.01 a	1.93 a-e	44.10 a-b	42.77 a	13.84 a-c	24.43 d-f	30.68 e-i	57.90 c	2.84 a-f
11.GG-20	0.93 b-c	18.19 c-e	1.42 h	29.51 c-f	25.59 b-d	12.15 a-d	31.96 a-d	41.79 a-b	71.31 a-c	2.82 a-f
12.STARR	0.78 c-e	17.18 e-h	1.59 e-h	35.25 a-d	27.40 b-d	12.29 a-d	30.80 a-d	29.45 e-i	68.18 a-c	2.68 b-f
13.NRCG-15049	0.55 h-i	14.64 h-k	1.77 b-h	21.71 e-f	25.90 b-d	10.84 a-d	29.23 a-e	27.71 f-j	77.04 a	2.64 b-f
14.ICGV-86590	1.06 b	19.71 a-d	1.52 f-h	34.40 a-e	29.81 b-c	10.94 a-d	27.14 b-f	32.49 c-h	61.53 bc	2.48 c-f
15.B-95	0.77 c-f	17.40 d-g	1.70 c-h	32.91 a-e	29.35 b-d	10.69 a-d	25.86 c-f	44.77 a	62.79 a-c	2.44 c-f
16.CHICO	0.50 i-j	14.18 i-l	1.97 a-d	25.84 c-f	27.98 b-d	10.55 a-d	27.68 a-e	30.60 e-i	65.00 a-c	2.35 d-f
17.NRCG-3498	0.67 d-i	14.63 h-l	1.63 d-h	22.08 e-f	23.82 c-d	9.59 c-f	29.30 a-e	34.44 c-f	70.46 a-c	2.15 e-g
18.JL-24	0.83 c-d	15.93 f-j	1.57 f-h	29.73 c-f	24.82 c-d	10.34 b-e	29.98 a-d	31.23 d-h	69.03 a-c	2.15 e-g
19.FeESG-8	0.83 c-e	13.74 j-l	1.83 b-f	30.50 c-f	25.09 b-d	8.50 d-g	23.71d-f	33.29 c-g	67.08 a-c	2.08 f-g

Contd....

Table2 Contd....

Genotype	RDW	SDW	SP	SPU	KP	KPU	PHI	HSM	SHP	KYP
20.ICG-4751	0.44 j	11.92 l	2.02 a-c	18.04 f	23.82 c-d	5.91 e-g	19.31 e-g	21.07 k-l	68.70 a-c	1.43 g-h
21.ICG-1955	0.66 e-i	15.16 g-k	1.75 b-h	28.17 c-f	26.47 b-d	5.49 f-g	17.60 f-g	24.31 i-l	72.72 a-c	1.33 h
22.GPBD-4	1.30 a	21.30 a-b	2.07 a-b	33.29 a-e	44.04 a	5.23 f-g	10.45 g	21.31 j-l	61.84 b-c	1.13 h
23.NRCG-162	0.56 g-j	12.82 k-l	2.27 a	28.24 c-f	29.06 b-d	3.46 g	9.63 g	16.49 l	63.70 a-c	0.78 h
P_0	0.84 a	16.30	1.70 b	27.83 b	4.60 a	10.57 b	27.37 b	30.93	66.07 b	2.29 b
P_{50}	0.70 b	16.06	1.79 a	28.82 b	4.23 b	11.96 a	29.36 a	31.65	70.06 a	2.82 a
P_{100}	0.68 b	16.35	1.83 a	29.62 a	4.34 b	10.59 b	25.94 b	31.41	67.87 b	2.43 b
Mean	0.74	16.24	1.77	28.76	4.39	11.04	27.56	31.33	68.0	2.51
LSD	0.03	0.46	0.06	1.28	0.18	0.86	1.79	NS	NS	0.15

Means followed by the same letter are not significantly different @$P \leq 0.05$

RDW = Root dry weight (g); SDW: Shoot dry weight (g) ; HSM: Hundred seed mass (g); SHP: Shelling percentage (%) ; KYP: Kernel yield per plant (g/plant); SP: shoot P- concentration (g/100g); SPU: Shoot P-accumulation (mg/plant) ; KP: Kernel P- concentration (g/100g); KPU: Kernel P-accumulation (mg/plant); PHI: P- harvest index

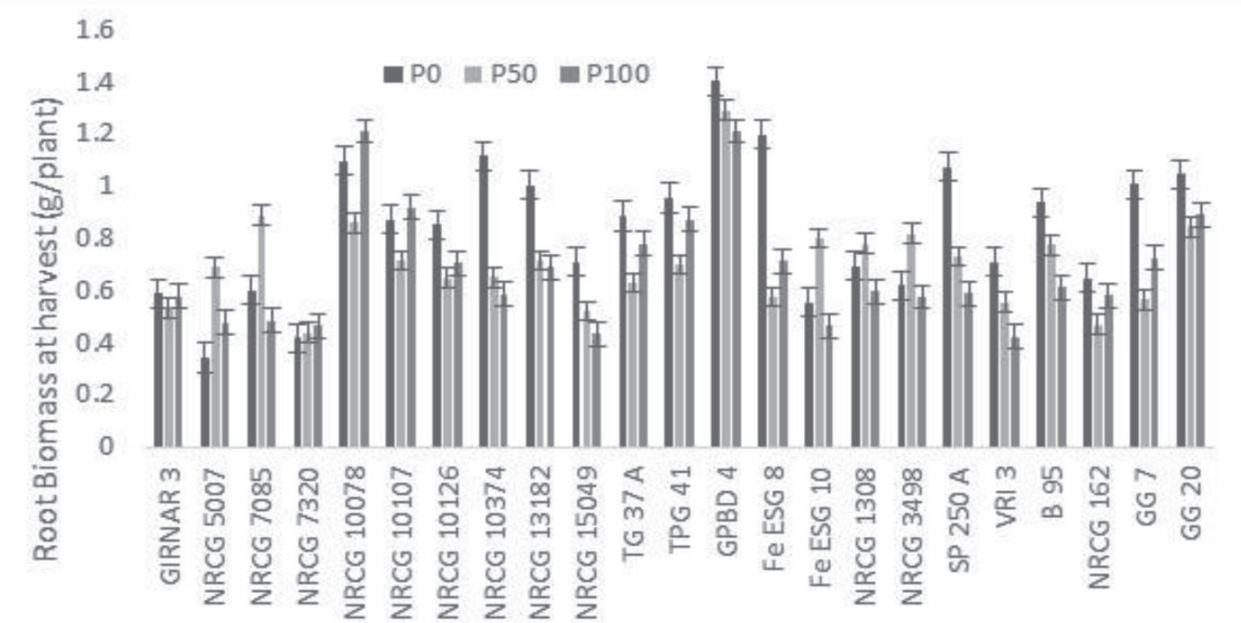

Fig. 1. Phosphorus and genotypic interaction effect on root biomass at harvest

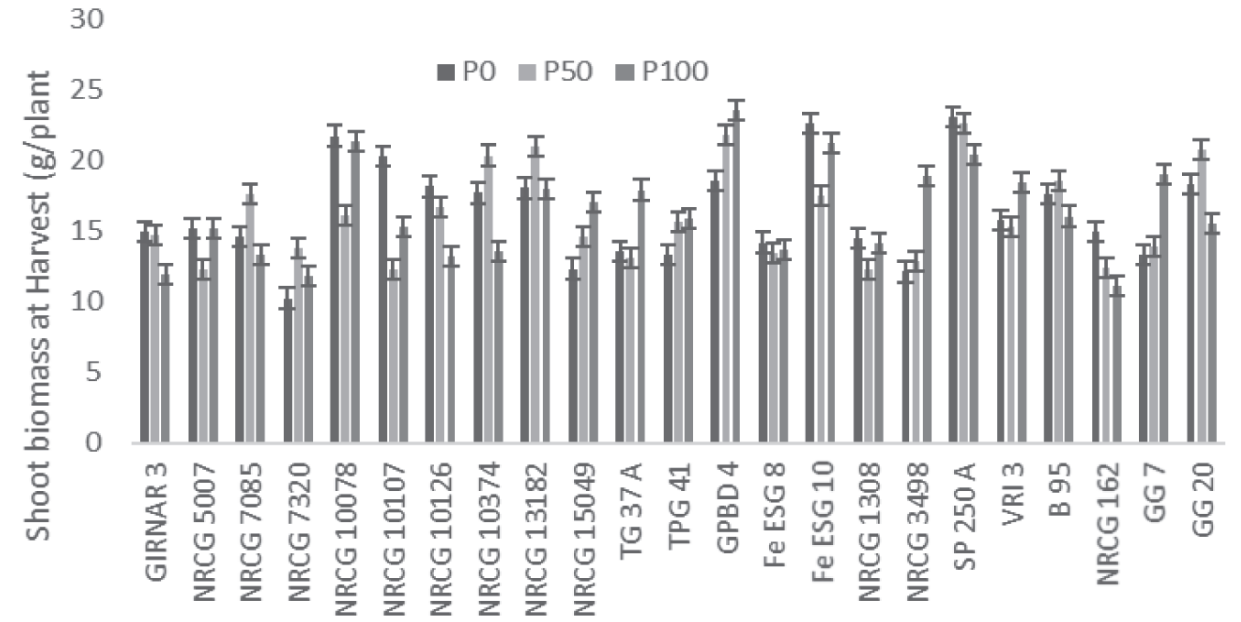

Fig. 2. Phosphorus and genotypic interaction effect on shoot biomass at harvest

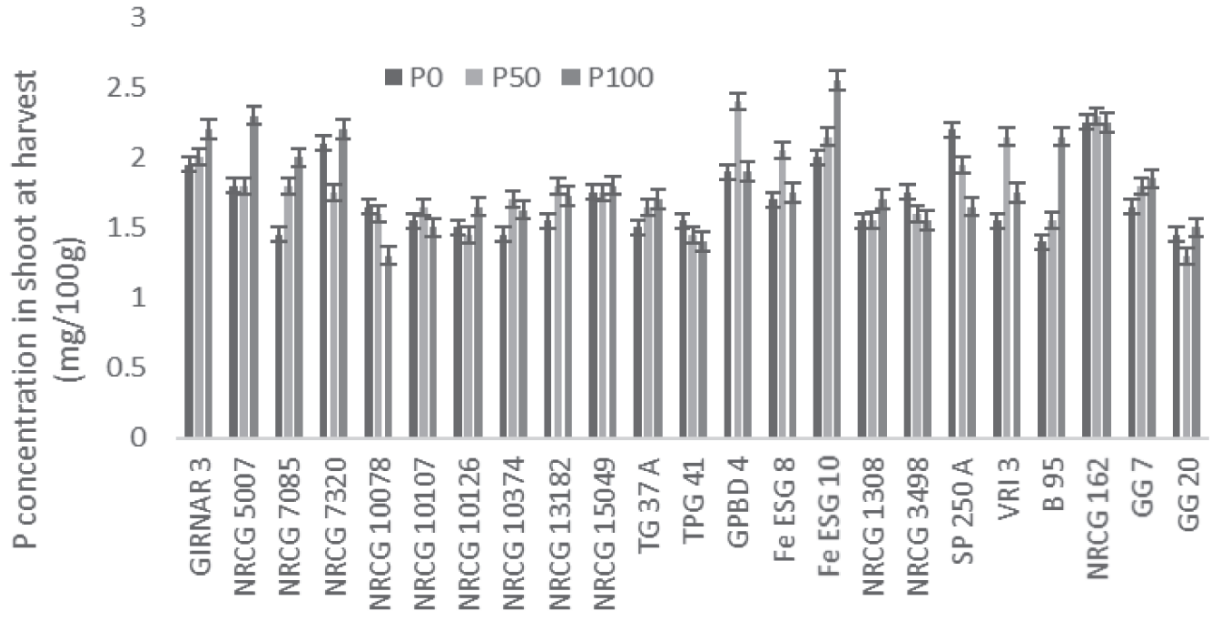

Fig. 3. P and genotypic interaction effect on P concentration in shoot at harvest

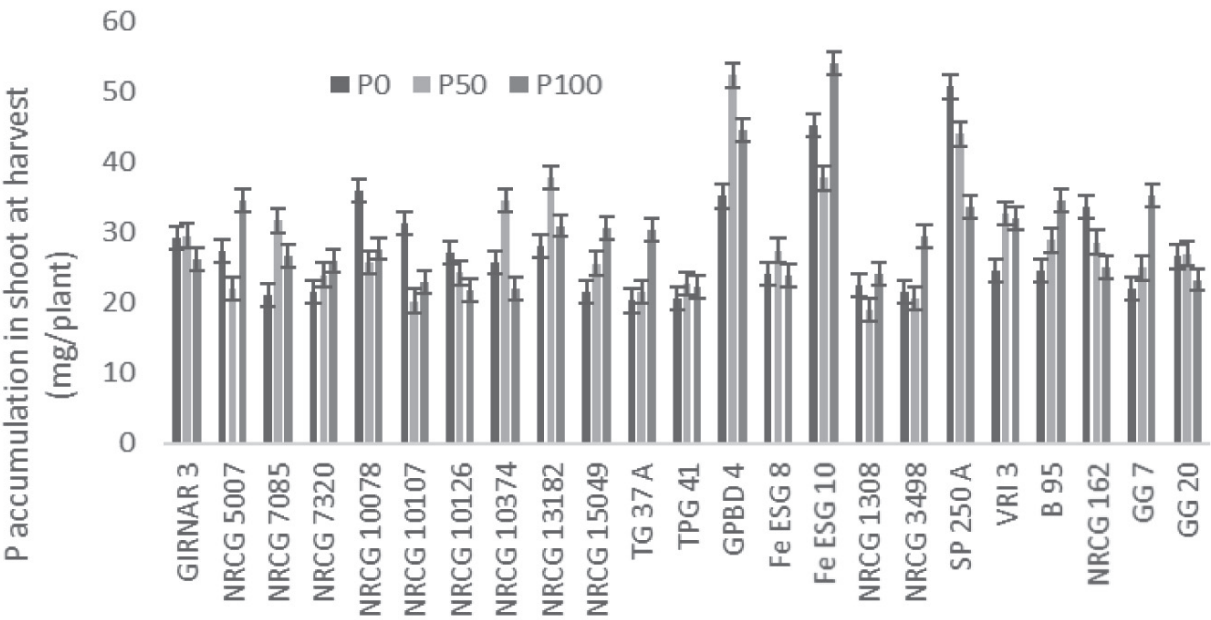

Fig. 4. P and genotypic interaction effect on P accumulation in shoot at harvest

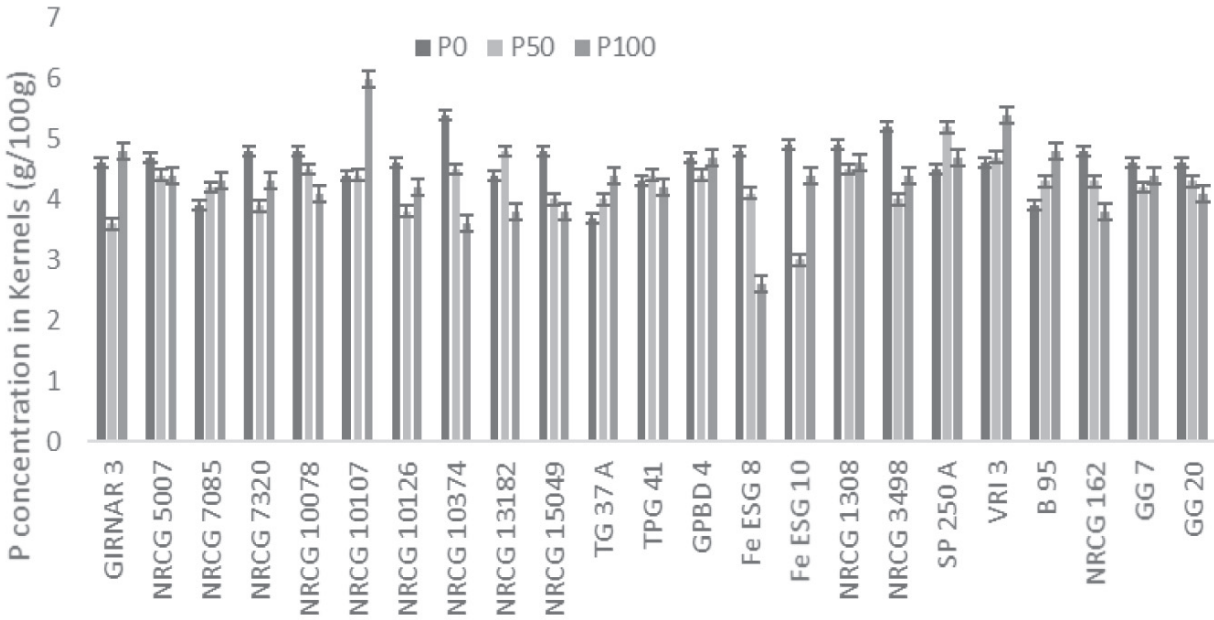

Fig. 5. P and genotypic interaction effect on P concentration in kernels

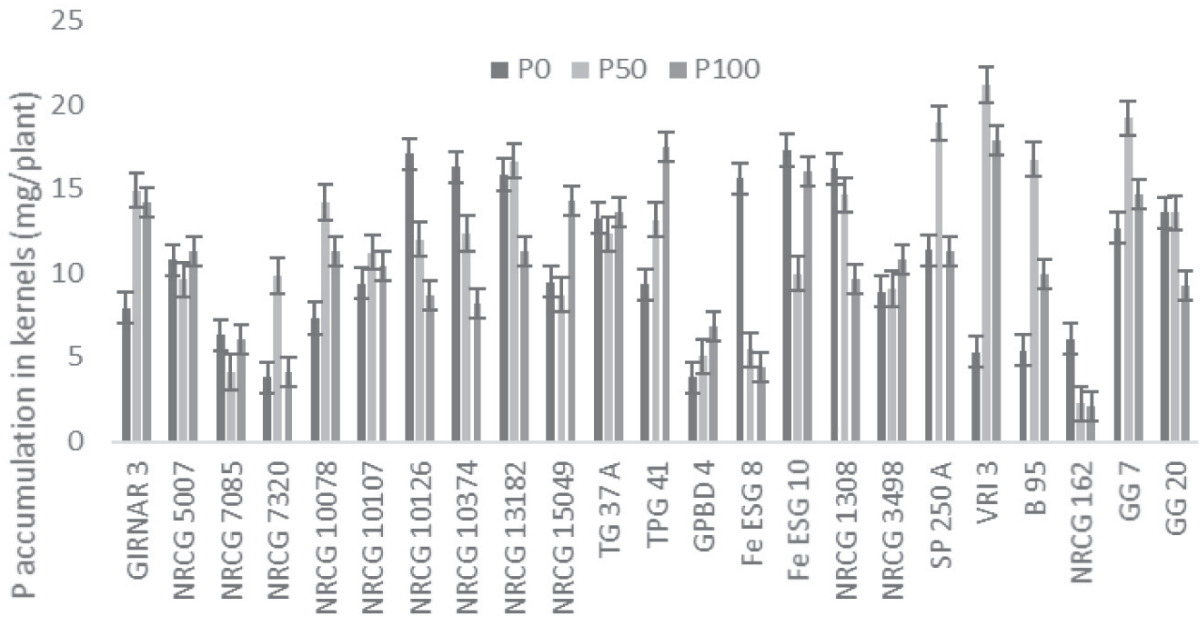

Fig. 6. P and genotypic interaction effect on P accumulated in kernels

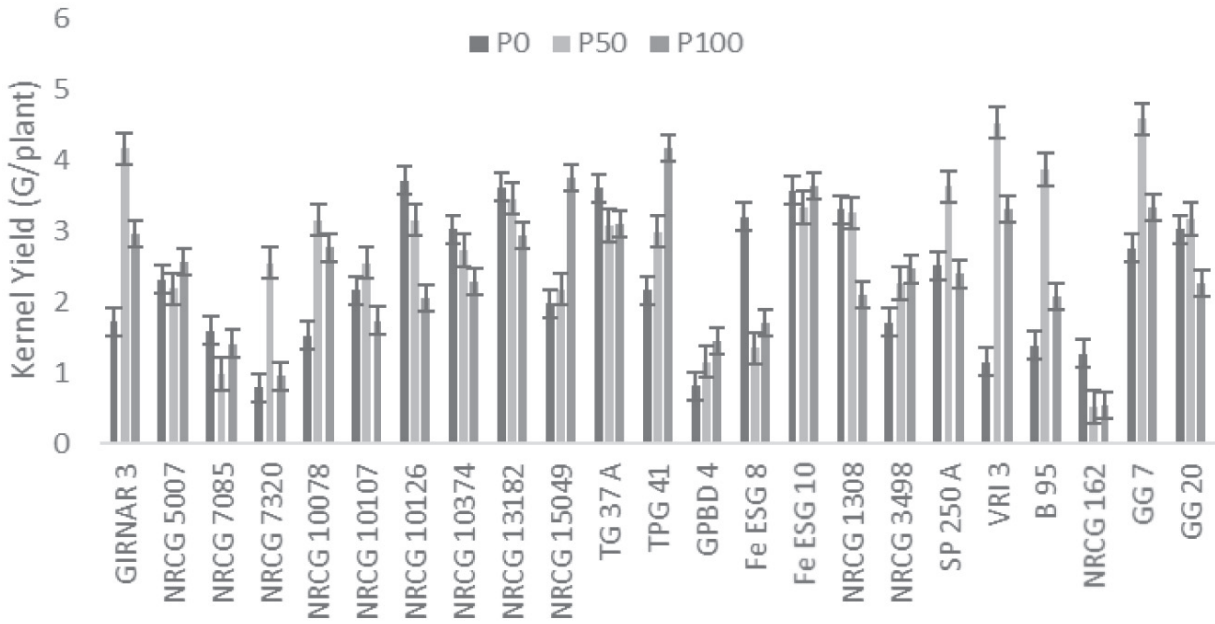

Fig. 7. P and genotypic interaction effect on kernel yield

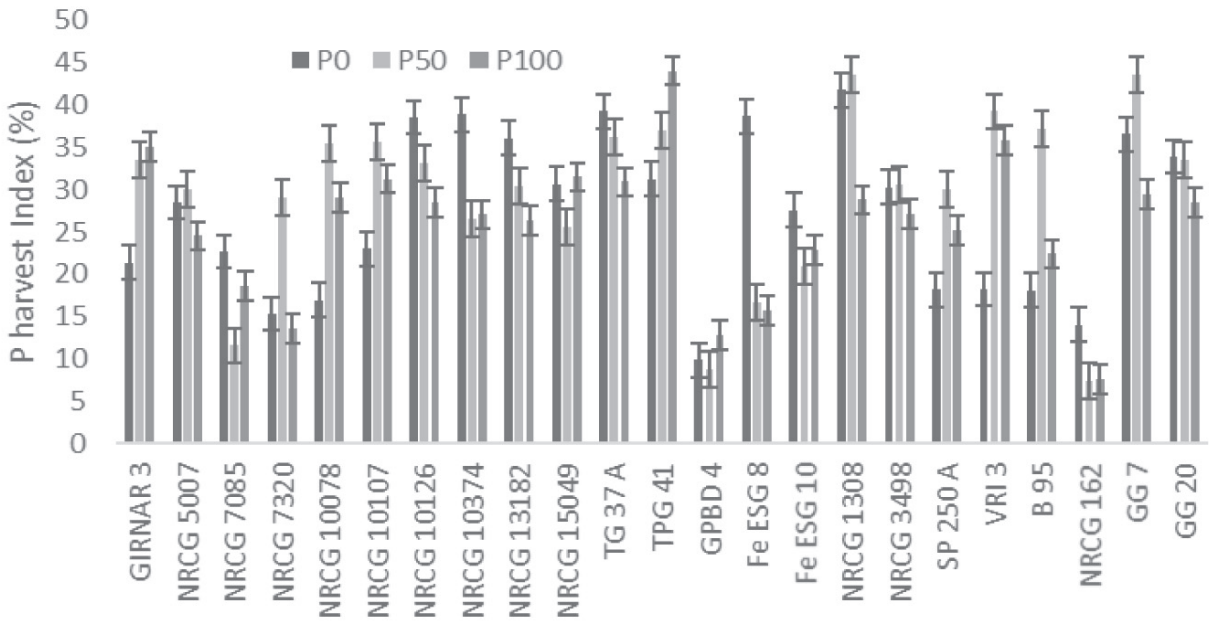

Fig. 8. P and genotypic interaction effect on P harvest index

proportional increase in yield is realistic until a limit is reached after which yield starts decreasing. Genotypes ICG-221, GG5, TG-37A and FeESG-10 had high yield under P limiting conditions but when P was supplied, they had yield loss and hence could be designated as 'high yielder – non-responsive' or 'efficient – non-responsive'. Non-responsiveness of these genotypes could be attributed to their inability to accumulate and translocate more P as a result they had low P-accumulation both in shoots and kernels (Fig. 4 and Fig. 6). Also excess P absorbed may have some inhibitory effect in the absorption of other mineral elements (Hopkins and Ellsworth, 2003). Under P-limiting conditions these 'high yielder – non-responsive' genotypes utilise P efficiently to produce high yields and as a result they have high P harvest index (Fig. 8). Genotypes such as Girnar-3, ICG-4751, ICGV-86590, JL-24, VRI-3, B-95 and GG-7 responded to P application only upto P_{50} and had yield reduction beyond this level. These genotypes are more suitable for optimal conditions where there are no limitations. Genotypes such as NRCG-15049, TPG-41, GPBD-4 and NRCG-3498 had low yield under P_0 conditions but responded to P application upto P_{100} and hence could be designated as 'low yielder - responsive'. These genotypes responded to P application by accumulating more P both in shoots and kernels but excess P-accumulation is not translated into higher yields. The identified 'high yielder – non responsive' and 'low yielder - responsive' genotypes may be used in breeding program to develop 'high yielder - responsive' genotypes.

CONCLUSION

The study revealed that genotypes differ in production of root system, kernel yield, shoot and kernel P-concentration, shoot and kernel P-accumulation and phosphorus harvest index. Soils of the experiment was calcareous in nature which limits the availability of phosphorus due to fixation by sesquioxides. Genotype FeESG-10 was outstanding in terms of shoot P-concentration and accumulation, kernel P-concentration and accumulation and kernel yield under low P treatment. It can be used for cultivation under low fertility tolerance. This genotype can be used in breeding program along with NRCG-15049, TPG-41, GPBD-4 or NRCG-3498 to breed high yielder and responsive genotypes.

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