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Differential Growth Behavior of Cotton Varieties at Adequate and Deficient Levels of Nitrogen and Phosphorus.

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Abstract
Seven cotton (Gossypitn hirsuturn L.) varieties were evaluated for growth and utilization efficiency of nitrogen (N) and phosphorus (P), in hydroponics using modified Johnson's solutions containing adequate (6.0 mM N and 0.20 mM P), and deficient levels of N (0.8 mM) and P (0.01 mM). Substantial differences were observed among varieties for accumulation of shoot dry weight (SDW), relative reduction in shoot biomass due to N-deficiency (NSF), and uptake by shoot in case of N, and root dry weight (RDW), root:shoot ratio (RSR), relative reduction in shoot biomass due to P-deficiency (PSF), concentration in shoot and uptake by shoot in case of P. Variety SLS-1 exhibited the minimum stress at N-deficiency (NSF = 34%) as well as P-deficiency (PSF = 59%) among all the varieties. A negative correlation (r =0.555, n =35) between SDW and RSR in P-stressed plants suggested increase RDW production at the cost SDW. Utilization efficiency in varieties remained unchanged in case of N-deficiency stress and decreased in case of P-deficiency stress as compared to control, and in both the cases differences among varieties remained statistically non-significant. Nutrient level X variety interaction was significant for all the parameters studied in case of P, whereas for N, the interaction was significant only for shoot dry weight, stress factor and uptake by shoot.

Key words: Grwoth behavior, cotton varieties, Nitrogen, Phosphorus

Introduction
Cotton is an important cash crop of Pakistan, ranking fifth in area and third in production in the world (Anonymous, 1998) and accounting for 60% of country's export earning and about 85% of its domestic oil production. In the recent past, intensive cropping system and use of high yielding varieties have depleted available nutrients from soil and poor yield of cotton is often an outcome of nutrient deficiency syndrome at farmers' fields, In addition, alkaline calcareous nature of our soils is responsible for low P-utilization efficiency by crops. Thus there is a need to optimize nutrient input (including P) according to crop requirement.

Low per acre use of plant nutrients and their low use efficiency in Pakistan soils are two important factors for low per acre yields of major crops as compared to other countries. Ever increasing prices of fertilizers due to increasing energy prices and depletion of world's mineable nutrient reserves have further aggravated the problem making fertilizer addition to soil cost intensive. This demonstrates the need to exploit ways to increase nutrient use efficiency by crops, under prevailing conditions.

The hypothesis that nutrient absorption and utilization by crops is genetically controlled was forwarded in early thirties. The work of last two decades has established sufficient evidence to believe that genotypic differences among crop species and varieties (in absorption and utilization of mineral nutrients) can be exploited to improve fertilizer-use efficiency, and to obtain higher productivity on nutrient deficient soils (Saric, 1987; Baligar and Fageria, 1990). Differential responses of different varieties of a crop to N (Sarma and Sarma, 1994; Jorgensen, 1997) and P (Caradus *et al*., 1995; Yan et al., 1995; Vegh *et al*., 1997) have been reported, making identification of nutrient efficient crops varieties a useful strategy for improving yields under low input agricultural systems in developing countries like Pakistan. Such exploitation will not only help in classifying the existing genetic material into nutrient-efficient or inefficient, responsive or non-responsive but will also provide information/data base for future breeding ventures. This study was initiated with the objective to evaluate seven cotton varieties for their efficiency to utilize nitrogen and phosphorus at deficient and adequate levels of these nutrients in the growth medium.

Materials and Methods
Seeds of seven cotton varieties (NIAB-86, NIAB-78, B-622, B-630, SLS-1, S-14 and CIM-70) were collected from Nuclear Institute for Agriculture and Biology (NiAB), Faisalabad, Central Cotton Research Institute (CCRI), Multan and Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Seeds were germinated in polyethylene coated iron trays containing washed sand, using distilled water during the course to maintain optimum moisture for germination and seedling establishment.

One week old uniform sized seedlings were transplanted in foam plugged holes of thermopal sheets floating on continuously aerated 200 L nutrient solutions it polyethylene lined iron tubs. One treatment was kept as control containing Johnson's solution (Johnson *et al*., 1957) having adequate levels of N (6.00 mM) and P (0.20 mM). Other two treatments were modified for deficient-N (0.8 mM) and deficient-P (0.01 mM) while keeping concentration of rest of the nutrients same as in control. pH of the solutions was maintained at 5.5 ± 0.5. The experiment was laid out in completely randomized factorial design with 5 replicates.

Plants were harvested after 28 days of transplanting. Harvested plants were washed with distilled water and blotted dry using filter paper sheets. Roots and shoots were separated and weighed after drying at 70°C for 48 h. Dried samples were finely ground and digested in diacid mixture of nitric acid and perchloric acid (4:1) for determination of P concentrations and in sulphuric acid + digestion mixture (K_2SO_4, $FeSO_4$ and $CuSO_4$; 10:1:0.5) for determination of nitrogen concentration using appropriate techniques.

The nutrient stress factors for varieties were calculated as $((SDW_{adequate\ level}-SDW_{deficient\ level})/SDW_{adequate\ level}\} \times 100$. Nutrient utilization in varieties was calculated as ((1/nutrient concentration in shoot, mg g^{-1}) × SDW, g $plant^{-1}$} (Siddiqi and Glass, 1981). The data were subjected to statistical treatments using Mstat-C program (Russell and Eisensmith, 1983).

Results and Discussion

Growth of cotton varieties at adequate and deficient levels of N and P: A difference of almost two fold in the ranges of SDW (4.83-8.57 g $plant^{-1}$) as well as RDW (0.41-0.79 g $plant^{-1}$) of the varieties, when grown with adequate N and P supply (Table 1), indicated wide variation among these varieties to exploit the same growth environment for production of biomass. Shoot dry weight decreased significantly at the deficient levels of N and P in the growth medium. However, differences in the SDW among the varieties were less conspicuous at the deficient levels as compared to the adequate level. S-14 accumulated maximum SDW in control treatment while NIAB-86 was most efficient in this regard at deficient level of N and B-622 at the deficient level of P. Under N deficiency, NIAB-86, B622, SLS-1 and CIM-70 produced more SDW than S-14 (the most efficient accumulator of SDW at control),whereas in case of P deficiency, all varieties except B-630 accumulated more SDW as compared to S-14. Similarly, SLS-1 produced the minimum SDW among all the varieties at adequate level of nutrients, whereas at the deficient P-level, it produced more SDW than CIM-70, S-14 and B-630. This indicates modification in the growth behavior of varieties under deficient and adequate supply of N and P in the growth medium.

Average RDW of varieties increased when exposed to N-deficiency but decreased in case of P deficiency as compared to control. The differences of RDW were statistically significant for nutrient levels, varieties, as well as variety X nutrient level interaction in case of P deficiency, but non-significant for of N-deficiency. In case of P deficiency, a positive correlation between root dry weight and total biomass (r = -0.656; n = 35) suggested that plants exhibiting more root growth exploited the growth medium more efficiently for biomass production.

A possible mechanism for plant adaptability under nutrient-stress conditions may he the diversion of growth from shoot to root (a high root:shoot ratio) and may be partially responsible for efficient exploitation of the growth medium (Fohse *et al.*, 1988). In this experiment, RSR increased

Table 1. Shoot *and* root dry weights, root:shool ratios and stress factors of seven cotton varieties at adequate and deficient levels of N and P.

Variety	Shoot dry weight (g $plant^{-1}$)				Root dry weight (g $plant^{-1}$)				Root: Shoot ratio				Stress factor (%)	
	Nitrogen		Phosphorus		Nitrogen		Phosphorus		Nitrogen		Phosphorus		Nitrogen	Phosphorus
	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.		
NIAB.78	5.15c	2.29	5.15c	1.98	0.41c	0.41b	0.41c	0.50ab	0.08	0.23ab	0.08	0.26bc	55.3ab	61.4bc
NIAB-86	5.95be	3.28	5.95be	2.11	0.49be	0.53b	0.49be	0.38b	0.08	0.17bc	0.08	0.19d	44.9bc	64.5be
B-622	6.12bc	3.14	6.12be	2.23	0.56be	0.55b	0.56bc	0.65a	0.09	0.25a	0.09	0.29ab	48.6bc	63.6bc
B-630	6.92b	2.46	6.92b	1.50	0.58be	0.56ab	0.58be	0.56b	0.08	0.23ab	0.08	0.31ab	64.5a	78.3a
SLS-1	4.83c	3.21	4.83c	1.96	0.51be	0.67ab	0.51be	0.4.1b	0.11	0.21abc	0.11	0.22cd	33.7c	59.4c
CIM-70	6.23bc	2.98	6.23Sc	1.76	0.62ab	0.73ab	0.62b	0.40b	0.10	0.25a	0.10	0.23cd	52.2ab	71.7ab
S-14	8.57a	2.84"	8.57a	1.55'	0.79a	0.5413	0.79a	0.48ab	0.09'	0.13c	0.09''5	0.33a	66.9a	81.9a
Mean	6.26A	2.89B	6.26A	1.87B	0.56B	0.62A	0.56A	0.47B	0.09B	0.22A	0.09B	0.26A	52.3	68.7

Means followed by same letters across columns are statistically similar with each other (P=0.051; '' Non-significant

Table 2. Concentration and uptake of N and P in shoot, and N- and P-utilization efficiency of seven cotton varieties at adequate and deficient levels of N and P.

Variety	Conc. in shoot (mg g^{-1})				Use efficiency (g^2 mg)				Uptake by shoot lmg plant $^{-1}$			
	Nitrogen		Phosphorus		Nitrogen		Phosphorus		Nitrogen		Phosphorus	
	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.	Adeq.	Def.
NIAB-78	40.1	18.8	2.44c	1.30	205cd	43	12.3d	2.56	0.13b	0.12b	2.19ab	1.55ab
NIA8-86	39.8	16.4	3.02bc	1.36	237be	53	18.1cd	2.85	0.15b	0.20a	1.98ab	1.58a
B-622	38.4	17.9	3.99a	1.43	234be	56	24.6ab	3.21	0.16ab	0.18ab	1.57b	1.57a
B-630	42.3	18.5	3.97a	1.58	289b	45	27.7a	2.36	0.17ab	0.138	1.82b	0.98ab
SLS-1	38.1	17.7	2.94bc	1.38	186c	57	14.2d	2.67	0.13b	0.18ab	1.65b	1.47ab
CIM-70	41.0	17.7	3.26b	1.50	226be	53	20.1be	2.66	0.15b	0.17ab	1.96ab	1.20ab
5-14	39.8"'	18.7°	3.45ab	1.72w	345a	53"	29.2a	2.66	0.22a	0.16ab	2.56a	0.94b
Mean	39.9A	18.0B	3.30A	1.47B	250A	51ES	20.9A	2.71B	0.16	0.16	1.96A	1.33B

Means followed by same letters across columns are statistically similar with each other (P=0.051; " Non-significant

ificantly in plants grown at deficient levels of N and P as compared to their adequate levels. But differences due to varieties and variety X nutrient level interaction were significant only in case of P. A negative correlation existed (r = -0.555; n =35) between SDW and RSR in case of P-stressed plants suggesting an increase in RDW production at the cost of SDW. Similar negative correlation between RSR and SDW was also reported by Caradus *et al*. (1995). No such correlation was, however, observed in case of N-stressed plants. Higher RSR under P-deficient conditions is well documented (Horst *et al*., 1993) and has been recommended by some as a suitable screening criterion against P-deficiency stress (Fageria *et al*., 1988). Relative reduction in SDW due to some nutrient deficiency in growth medium is termed as stress factor (%) and generally, varieties showing low values for stress factor are preferred in screening programmes. In this experiment, stress factor was of the higher order in case of P -deficiency compared to N-deficiency. In case of P-deficiency, no variety produced a stress factor less than 50%, whereas in case of N-deficiency, NIAB 86, B-622 and SLS-1 depicted stress factors less than 50% indicating better adaptability of these varieties to N deficiency as compared to P-deficiency. Nevertheless, differences of stress factors among varieties were statistically significant in both N- and P-deficiencies.

Nitrogen and Phosphorus shoot concentration and uptake: Ranges of shoot concentrations of N and P, shoot uptakes of N and P and N- and P-utilization efficiencies of 7 cotton genotypes are given in Table 2. Both shoot concentration and uptake of N and P decreased significantly with their deficiency in the growth medium and the effects of varieties and variety X nutrient level interactions were also significant for both N- and P-uptake by shoot. The effect of varieties and varieties X nutrient level interactions were, however, non-significant in case of N while signiticant in case of P (Table 2) when concentrations of N and P in shoot were considered. The effects of nutrient levels in the growth medium (for both N and P) were statistically significant for shoot concentrations of these nutrients.

In this experiment, differences in nutrient utilization efficiencies due to varieties remained non-significant for both N and P (Table 2). However, nutrient utilization efficiencies decreased with the deficiency of P in the growth medium while remained unchanged in case of N-deficiency. This implies that as the concentration of P decreased in the growth medium, less dry matter was being produced for each unit of the nutrient absorbed. This may explain lesser adaptability of the varieties included in this study to P deficiency stress, as nutrient utilization efficiency of efficient varieties increase with decreasing nutrient concentration in the growth medium (Ashraf, 1996).

Nutrient-use efficiency is generally considered to result from either a better ability in uptake of nutrients or better efficiency in using nutrients already available in the tissue (Blum, 1988). In this experiment, both N and P uptake and their use efficiencies had high correlation with SDW ($r > 0.800$; $n=35$), in all the treatment. However, N-stressed plants depicted a significant positive correlation between N-uptake by shoot and N-utilization efficiency (r = 0.795; n = 35). This relationship was not as strong for P in P-stressed plants (r = 0.472; n = 35), or the plants were relatively less efficient utilizers of P taken up by their shoots. Since varieties studied in this experiment had better adaptability to N-deficiency stress as compared to P-deficiency stress (based on % stress factor), it may be conceived that efficient utilization of the nutrient taken up by the shoot may make a plant better adaptable to nutrient-deficiency stress conditions. Sattelmacher *et al*. (1994) also reported varieties having higher nutrient-utilization efficiency to be more adaptable to nutrient-deficient conditions.

It is concluded from this study that wide differences in growth exist among cotton varieties exposed to same N and P-concentrations in the growth medium. Varieties having better efficiency to utilize nutrients taken up by shoot may adapt better to nutrient deficient conditions.

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