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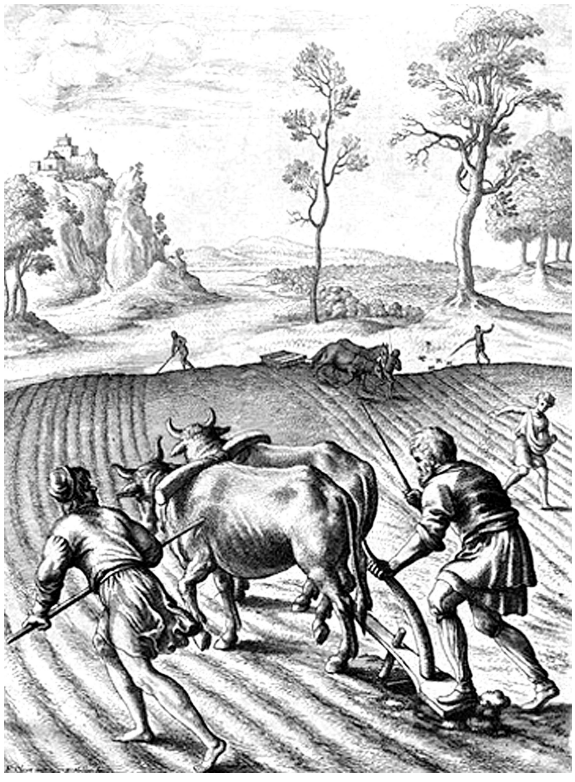

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Phosphorus Use Efficiency of Soybean as Affected by Phosphorus Application and Inoculation

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Abstract: To study the effect of inoculation and phosphorus application on soybean nutrition, an experiment was conducted at two locations in the North West Frontier Province (NWFP) of Pakistan. Four levels of P viz., 0, 40, 60, and 80kg ha^{-1} of P_2O_5, and two levels of inoculation, no inoculation and inoculation with *Bradyrhizobium japonicum* were studied. Data were recorded on biological yield, seed yield, and P concentration in biological yield, and P uptake efficiency (PUPE), P utilization efficiency (PUTE), P use efficiency (PUE), fertilizer P uptake efficiency (FPUPE), fertilizer P utilization efficiency (FPUTE), fertilizer P use efficiency (FPUE) were calculated. Phosphosrus application slightly increased PUPE but decreased PUTE and PUE. Increase in P application increased FPUPE, FPUTE and FPUE. Inoculation increased PUPE, PUE and FPUPE at both locations but increased PUTE, FPUTE and FPUE at NWFP-AU only. Due to increase in yield and improvement in nutritive quality of the soybean seed and shoot, inoculation and P application is necessary for higher protein and oil yields from soybean seeds as well as for higher forage protein yields from soybean planted for forage.

Key words: Soybean, *Glycine max* (L.) Merrill, *Rhizobium japonicum*, phosphorus, uptake efficiency, utilization efficiency, use efficiency

Introduction

Phosphorus is an essential element and its application is more important for growth, development, and yield of soybean [*Glycine max* (L.) Merrill], because of the leguminous nature of the crop. Inoculation is also necessary for nodulation, N-fixation and yield of the crop. Ibrahim and Mahmoud (1989) reported that inoculation decreased P content of soybean. P uptake by soybean was increased by application of 90mg P per kg soil but despite this P concentration in the above ground plant parts was not affected by P application as well as inoculation (Pongsakul and Gensen, 1991). They also reported that root weight was increased by up to 60 % by P application but generally P uptake was not affected by P application. P application increased P concentration in soybean leaves (Synder *et al.*, 1993, Islam, 1964) . However phosphorus application and inoculation affect the yield of soybean through their effects on phosphorus use efficiency and its components (PUPE and PUTE), that has not been studied in NWFP. Therefore, an experiment was designed to have a deeper insight into P nutrition of soybean and its relation to economic yield.

Materials and Methods

The experiment was conducted at Nuclear Institute for Food and Agriculture (NIFA) and NWFP Agricultural University, Peshawar, during 2000-2001. The soil of NIFA was loamy sand, low in N, and organic matter, moderately low in P, and alkaline in reaction with a pH of 8.2. The soil of NWFP-AU was silty clay, low in N, organic matter and P and alkaline in reaction with a pH of 7.7. Effects of four levels of P viz., 0, 40, 60 and 80kg ha^{-1} of P_2O_5, and two levels of inoculation, no inoculation and inoculation with *Bradyrhizobium japonicum*, were studied in the experiment, which was conducted using randomized complete block design (Steel & Torrie, 1980). Plot size was 10x2.5m^2. The following parameters were calculated to know the nutrition of soybean.

Phosphorus uptake efficiency (PUPE) = P in plant/P in soil
Phosphorus utilization efficiency (PUTE) = Yield/P in plant
Phosphorus use efficiency (PUE) = Yield /P in soil
Fertilizer P uptake efficiency (FPUPE) =
(P in fertilized plants - P in control plants)/P applied
Fertilizer P utilization efficiency (FPUTE) =
(Yield of fertilized plots -Yield of control plots)/
(P in fertilized plants - P in control plants)
Fertilizer P use efficiency (FPUE) =
(Fertilized plot yield – control plot yield)/P applied

Results and Discussion

Phosphorus uptake efficiency, kg phosphorus in plants per kg phosphorus in soil, was much greater at NWFP-AU than at NIFA (Table 1). PUPE increased with phosphorus application and with inoculation at both the locations. Inoculated soybeans had greater PUPE than uninoculated soybean at both the locations. There was steady increase in PUPE with increase in rate of P applied at NIFA, however, at NWFP-AU, the lower level of P application had only slight effect but the highest rate of 80kg P per ha increased PUPE. These results are in line with the previous work of Pongsakul and Gensen (1991).

Table 1: Phosphorus uptake efficiency of soybean as affected by phosphorus application and inoculation

P_2O_5	NIFA			NWFP-AU		
Kg ha^{-1}	Uninoc.	Inoc.	Mean	Uninoc.	Inoc.	Mean
Control	0.06	0.08	0.07	0.41	0.48	0.45
40	0.08	0.09	0.09	0.41	0.49	0.45
60	0.09	0.11	0.10	0.44	0.48	0.46
80	0.10	0.12	0.11	0.47	0.54	0.50
Mean	0.08	0.10		0.43	0.50	

Uninoc., Uninoculated and Inoc., Inoculated

Table 2: Phosphorus utilization efficiency of soybean as affected by phosphorus application and inoculation

P_2O_5	NIFA			NWFP-AU		
Kg ha^{-1}	Uninoc.	Inoc.	Mean	Uninoc.	Inoc.	Mean
Control	138.72	131.36	135.04	61.58	62.18	61.88
40	98.58	103.01	100.79	48.94	48.11	48.53
60	123.59	106.32	114.96	43.43	49.81	46.62
80	119.51	102.58	111.04	38.20	44.56	41.38
Mean	120.10	110.82		48.04	51.17	

Table 3: Phosphorus use efficiency of soybean as affected by phosphorus application and inoculation

P_2O_5	NIFA			NWFP-AU		
Kg ha^{-1}	Uninoc.	Inoc.	Mean	Uninoc.	Inoc.	Mean
Control	8.04	9.96	9.00	25.50	30.15	27.82
40	8.25	9.60	8.93	20.30	23.44	21.87
60	10.79	11.74	11.27	19.25	23.95	21.60
80	11.55	12.50	12.02	17.83	23.99	20.91
Mean	9.66	10.95		20.72	25.38	

Table 4: Fertilizer P uptake efficiency of soybean as affected by phosphorus application and inoculation

P_2O_5	NIFA			NWFP-AU		
Kg ha^{-1}	Uninoc.	Inoc.	Mean	Uninoc.	Inoc.	Mean
Control	-	-	-	-	-	-
40	0.26	0.21	0.23	0.42	0.49	0.45
60	0.22	0.27	0.24	0.50	0.47	0.48
80	0.23	0.28	0.25	0.54	0.61	0.57
Mean	0.24	0.25		0.48	0.53	

Table 5: Fertilizer P utilization efficiency of soybean as affected by phosphorus application and inoculation

P_2O_5	NIFA			NWFP-AU		
Kg ha^{-1}	Uninoc.	Inoc.	Mean	Uninoc.	Inoc.	Mean
Control	-	-	-	-	-	-
40	37.53	33.91	35.72	15.14	10.91	13.03
60	105.57	74.12	89.85	16.13	27.01	21.57
80	102.94	75.94	89.44	13.99	25.73	19.86
Mean	82.01	61.33		15.08	21.22	

Table 6: Fertilizer P use efficiency of soybean as affected by phosphorus application and inoculation

P_2O_5	NIFA			NWFP-AU		
Kg ha^{-1}	Uninoc.	Inoc.	Mean	Uninoc.	Inoc.	Mean
Control	-	-	-	-	-	-
40	9.71	7.16	8.44	6.30	5.38	5.84
60	23.32	19.86	21.59	7.99	12.78	10.39
80	23.47	21.12	22.30	7.52	15.70	11.61
Mean	18.33	16.47		7.7	11.29	

Phosphorus utilization efficiency, kg of seed yield divided by kg of P in plant, measure the efficiency with which P in plant is utilized for producing economic yield. PUTE was higher in NIFA than in NWFP-AU (Table 2). Phosphorus application decreased PUTE of soybean, however, the differences among the treatments were greater at NIFA and slight at NWFP-AU. Inoculation decrease the PUTE at NIFA but increased at NWFP-AU.

Phosphorus use efficiency is a measure of the economic yield produced per unit P in the soil. PUE was higher at NWFP-AU than at NIFA (Table 3). Averaged over all the P levels, inoculation increased PUE of soybean at both the locations with much greater effect at NWFP-AU than at NIFA. At NIFA, P application at the rate of 60 and 80kg ha^{-1} increased PUE as compared with control and 40kg ha^{-1} of P. At NWFP-AU, the three rates of P application decreased PUE as compared with control plots. Thus P application increased PUE at NIFA but decreased at NWFP-AU.

Fertilizer P uptake efficiency was higher at NIFA than at NWFP-AU (Table 4). Average over the three P application rates, inoculation slightly increased FPUPE of soybean. Similar results were reported by Snyder *et al.* (1993). At NIFA, FPUPE decreased slightly with increase in rate of applied P in uninoculated plots but increased in inoculated plots. At NWFP-AU, FPUPE increased with increase in rate of P applied in both inoculated and uninoculated plots.

Though Fertilizer P utilization efficiency was greater at NIFA than at NWFP-AU, FPUTE decreased with inoculation at NIFA but decreased with inoculation at NWFP-AU (Table 5). FPUTE increased with increase in rate of applied P at both the locations in inoculated as well as uninoculated plots except a slight decrease at the highest level in uninoculated plots.

Fertilizer P use efficiency of soybean was higher at NIFA than at NWFP-AU (Table 6). Averaged over the three P rates, FPUE increased with inoculation at NWFP-AU but decreased with inoculation at NIFA. FPUE increased with increase in the applied P from 40 to 80kg ha^{-1} with some leveling off at the highest P rate in uninoculated plots.

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