ZINC RESPONSE IN PIGEON PEA AS INFLUENCED BY GENOTYPIC VARIABILITY*

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KEY WORDS

Differential susceptibility Legume Pigeon pea P-distribution Nutrient balance Zn-distribution.

ABSTRACT

Seven improved cultivars of pigeon pea (*Cajanus cajan* (L.) Mill sp.) were evaluated at 0 (original Zn deficient soil), 5 and 50 ppm Zn levels under greenhouse conditions. Plants were harvested at 6 weeks after sowing and at maturity. Responses to 5 ppm Zn in shoot at 6 weeks of growth, and in leaf, stem, pod-hull and grain at maturity ranged from 63 to 387, 37 to 116, 15 to 73, 9 to 145 and 51 to 200%, respectively. Application of 50 ppm Zn in most of the cultivars did not markedly affect the yield of different plant parts. Zinc concentration at 0 Zn level in shoot at 6 weeks of growth and in leaf, stem, pod-hull and grain of different genotypes varied from 9.8 to 14.5, 13.7 to 21.2, 10.8 to 16.7, 4.17 to 5.83 and 9.2 to 16.7 ppm, respectively, and the increase in concentration with 5 ppm applied Zn ranged from 28 to 248, 28 to 89, 27 to 85, 20 to 142, and 105 to 254 per cent, respectively. The concentration further increased with an increase in Zn level to 50 ppm. There was less variation in the yield and tissue Zn concentration of different genotypes after Zn application. Phosphorus concentration at 0 Zn level in shoot at 6 weeks of growth, and in leaf, stem, pod-hull and grain of different genotypes varied from 0.50 to 0.71, 0.18 to 0.31, 0.11 to 0.24, 0.15 to 0.20 and 0.43 to 0.58%, respectively. Zinc decreased P in all plant parts but relative decrease was more in vegetative parts than in grain. The variability in Zn response among pigeon pea genotypes could partly be attributed to the maintenance of proper P/Zn balance in metabolically active plant parts, such as, leaf, and partly to their capacity to exploit soil Zn and to translocate it to the above-ground parts.

INTRODUCTION

Pigeon pea (*Cajanus cajan* (L.) Mill Sp.) is an important crop of semi-arid tropics, and may respond to Zn application. However, the studies on Zn response in pigeon pea particularly in relation to genotypic variability are not documented in the literature. Genotypic variability in Zn response is known to occur in legumes like Navybean[1] and cowpea[6]. Ambler and Brown[1] attributed differential susceptibility to Zn deficiency in two Navybean cultivars to their

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differential P and Fe absorption capacity. But in cereals like wheat and corn Shukla and Hans Raj[7,8] found that response to Zn in different genotypes was associated with their capacity to exploit soil Zn and its translocation to shoot. Keeping the above in view, the present investigation was undertaken to evaluate the influence of genetic variability on Zn response in some improved cultivars of pigeon pea.

MATERIALS AND METHODS

A greenhouse experiment was conducted in polythene lined clay pots of 25 cm dia. filled with 4 kg of a Zn-deficient, loamy sand (typic torripsamments) soil of pH 7.8, C.E.C. (meq/100 g) 4.1, organic carbon 0.17% and available Zn (DTPA extractable) 0.46 ppm. DTPA extractable Zn was determined according to Lindsay and Norvell[4]. All other soil properties were determined by the routine laboratory procedures as described by Kanwar and Chopra[2].

Seven improved cultivars of pigeon pea, H 72–44, H 73–20, Pant A–1, Pant A–2, Pant A–3, Parbhat and T 21 were evaluated at 0 (original soil – also referred as Zn stress condition), 5 and 50 ppm Zn supplied as $ZnSO_4 \cdot 7H_2O$. Each treatment received a basal application of N, P, and K @ 25, 50, and 50 ppm, respectively, and replicated three times. Four plants/pot were grown, two plants were harvested after six weeks of sowing and the rest at maturity. Appearance and severity of deficiency symptoms were recorded for each cultivar. Deionized water was used for irrigation. Each plant sample was washed successively in deionized, acidified-deionized and double glass distilled water immediately after harvesting. The plant samples, except grain were dried in a forced air-draft oven at 70°C. Grain samples were dried in sun and then in oven at 60°C. Dry matter yield of shoots at 6 weeks of growth, and of leaf, stem, pod-hull and grain at maturity were recorded for each cultivar separately. Plant samples were ground in a Wiley mill with stainless steel parts. One-half a gram of each sample was digested with 10 ml diacid mixture of distilled HNO_3 and $HClO_4$ in the ratio of 5:1. Zinc and Fe in the digested samples were determined by atomic absorption spectrophotometry. Phosphorus was determined by phosphomolybdate yellow colour method according to Koenig and Johnson[3].

RESULTS AND DISCUSSION

Deficiency symptoms

All cultivars showed Zn deficiency symptoms but differed in their intensity and general appearance. The cultivars, Pant A–1, and A–2, and T 21 showed severe growth depression, reduced leaf size as well as typical Zn deficiency symptoms, which were characterized by yellowish-white interveinal chlorisis appearing first on 7th leaf, and then on 6th leaf, followed by turning of yellowish-white chlorotic areas into reddish brown and leaf shedding. Whereas, cultivar Pant A–3 showed primarily typical Zn deficiency symptoms without much growth depression. After shedding of 7th and 6th leaf, the symptoms appeared on 8th and other leaves. The appearance of symptoms first on 7th trifoliate leaf then on 6th was rather very typical observation. Normally, under acute Zn deficiency conditions in most of the crop plants, symptoms appear first on 2nd and 3rd leaf.

Yield response

There was a considerable variability among genotypes in their response to Zn deficiency in soil (Table 1). The response to 5 ppm Zn over 0 Zn level in shoot at six-weeks of growth and in leaf, stem, pod-hull, and grain at maturity of different genotypes ranged from 63 to 387, 37 to 116, 15 to 73, 9 to 145 and 51 to 200 percent, respectively (Table 1). The response pattern of only some of cultivars was changed with increase in Zn level to 50 ppm. The above results showed that the magnitude of Zn response among genotypes may also vary with the stage of growth and plant part sampled. Among the cultivars, the grain

Table 1. Dry matter yield of different plant parts of seven cultivars of pigeon pea as affected by Zn level at two stages of growth

Cultivar	Zn levels (ppm)				% response over control	
	0	5	50	Mean	5	50 ppm Zn
Shoot yield at 6 weeks, g/pot						
H 72–44	1.27	3.37	3.90	2.85	165	207
H 73–20	1.23	2.90	2.73	2.29	136	122
Pant A–1	0.93	2.37	2.67	1.99	155	187
Pant A–2	0.97	2.27	2.93	2.06	134	202
Pant A–3	1.53	2.50	3.13	2.39	63	104
Parbhat	0.70	2.47	3.17	2.11	253	353
T 21	0.63	3.07	3.03	2.24	387	381
Zn level mean	1.04	2.71	3.08			
Leaf yield at maturity, g/pot						
H 72–44	3.1	6.3	7.9	6.1	54	93
H 73–20	2.9	4.5	4.7	4.0	55	62
Pant A–1	3.4	6.0	5.3	4.9	76	56
Pant A–2	2.5	5.4	4.2	4.0	116	68
Pant A–3	4.0	5.5	5.4	5.0	37	35
Parbhat	3.4	5.3	5.7	4.8	56	68
T 21	4.5	6.6	6.9	6.0	47	53
Zn level mean	3.5	5.6	5.7			

Table 1 (continued)

Cultivar	Zn levels (ppm)				% response over control	
	0	5	50	Mean	5	50 ppm Zn
Stem yield at maturity, g/pot						
H 72–44	15.3	23.6	24.1	21.0	54	57
H 73–20	12.6	20.8	21.4	18.3	65	70
Pant A–1	8.6	12.5	14.6	11.9	45	70
Pant A–2	9.4	13.7	13.2	12.1	46	40
Pant A–3	14.0	16.1	15.8	15.3	15	13
Parbhat	8.1	14.0	13.2	11.8	73	63
T 21	10.8	17.7	16.7	15.1	64	55
Zn level mean	11.2	16.9	17.0			
Pod-hull yield at maturity, g/pot						
H 72–44	2.8	5.8	6.3	5.0	107	125
H 73–20	3.7	5.1	5.7	4.8	38	54
Pant A–1	3.1	7.6	7.0	5.9	145	126
Pant A–2	4.5	4.9	5.6	5.0	9	24
Pant A–3	5.6	12.7	10.3	9.5	127	84
Parbhat	3.7	5.4	6.0	5.0	46	62
T 21	3.7	7.6	7.3	6.2	105	97
Zn level mean	3.9	7.0	6.9			
Grain yield at maturity, g/pot						
H 72–44	3.3	7.4	8.2	6.3	124	148
H 73–20	5.3	9.2	8.5	7.7	74	60
Pant A–1	3.8	11.4	11.4	8.9	200	200
Pant A–2	4.4	8.7	8.7	7.3	98	98
Pant A–3	6.7	10.1	10.0	8.9	51	49
Parbhat	6.1	9.9	10.0	8.7	62	64
T 21	3.8	8.5	10.4	7.6	124	174
Zn level mean	4.8	9.3	9.6			

C.D. (P = 0.05) for differences among means of cultivars, shoot-6 weeks (0.35), leaf (.35), stem (1.37), pod-hull (.68) and grain (.69); means of Zn levels, shoots-6 weeks (0.23), stem (.89), pod-hull (.45), and grain (.45); means of cultivar × Zn levels, shoots-6 weeks (.61), leaf (.93), stem (2.38), pod-hull (1.19), and grain (1.21).

yield of pant A–1 was about $\frac{1}{2}$ of Pant A–3 under Zn stress conditions, whereas after Zn application, the yield of Pant A–1 was about 14 percent more than Pant A–3 (Table 1). This observation suggests that while evaluating genotypes for their yield potential, the interaction of genotype with the soil's nutrient status should be given due consideration.

A comparison of leaf, stem, pod-hull and grain yield of different cultivars (Table 1) showed that Pant A–1 and Prabhat yielded proportionately more grain than other varieties, whereas H 72–44 yielded more of stem and leaf. The pod-hull yield of Pant A–3 was proportionately much more than grain yield. This showed that there was considerably less grain filling than the number of pod formed. These differences among cultivars could be attributed to their genetic variability.

Zinc concentration

The Zn concentration at 0 Zn level in shoot at 6 weeks of growth, and in leaf, stem, pod-hull, and grain at maturity ranged from 9.8 to 14.5, 13.7 to 21.2, 10.8

Table 2. Zinc concentration in different plant parts of seven cultivars of pigeon pea as affected by zinc level at two stages of growth

Cultivar	Zn levels (ppm)				% response over control	
	0	5	50	Mean	5	50 ppm Zn
Zn conc. in shoot at 6 weeks, ppm						
H 72–44	9.8	22.2	49.1	27.0	126	400
H 73–20	13.5	18.6	39.8	24.3	28	175
Pant A–1	10.3	21.7	39.3	23.8	110	280
Pant A–2	10.8	37.7	48.0	32.2	248	343
Pant A–3	11.4	17.6	49.6	26.2	54	336
Parbhat	12.4	18.6	44.4	25.1	50	258
T 21	9.8	19.6	38.2	22.6	100	289
Zn level mean	11.3	22.3	44.1			
Zn conc. in leaf at maturity, ppm						
H 72–44	13.7	23.3	54.2	30.4	70	294
H 73–20	17.5	24.7	39.2	27.1	41	124
Pant A–1	15.8	22.4	35.0	24.4	42	121
Pant A–2	16.2	20.8	47.1	28.0	28	190
Pant A–3	21.2	30.8	90.8	47.6	46	329
Parbhat	15.8	30.0	35.7	27.2	89	125
T 21	15.0	19.7	37.1	23.9	32	147
Zn level mean	16.5	24.5	48.4			

Table 2 (continued)

Cultivar	Zn levels (ppm)				% response over control	
	0	5	50	Mean	5	50 ppm Zn
Zn conc. in stem at maturity, ppm						
H 72–44	13.7	17.5	48.3	26.5	27	251
H 73–20	12.9	22.1	49.2	28.1	71	281
Pant A–1	12.9	17.1	36.2	22.1	32	181
Pant A–2	13.7	25.4	48.7	29.3	85	254
Pant A–3	16.7	25.8	61.7	34.7	55	270
Parbhat	13.3	19.2	37.9	23.5	44	184
T 21	10.8	15.0	38.7	21.5	38	258
Zn level mean	13.4	20.3	45.8			
Zn conc. in pod-hull at maturity, ppm						
H 72–44	4.6	9.2	36.7	16.8	100	701
H 73–20	5.0	9.2	26.2	13.5	83	425
Pant A–1	4.2	7.9	23.7	11.9	90	469
Pant A–2	5.0	12.1	32.5	16.5	142	550
Pant A–3	5.8	10.0	29.6	15.1	71	407
Parbhat	4.2	5.0	15.1	8.1	20	262
T 21	4.6	7.9	15.0	9.2	73	227
Zn level mean	4.8	8.7	25.5			
Zn conc. in grain at maturity, ppm						
H 72–44	10.8	37.5	51.7	33.3	246	377
H 73–20	9.2	32.5	50.8	30.8	254	454
Pant A–1	14.2	30.0	49.6	31.2	112	250
Pant A–2	12.1	29.8	53.7	35.0	224	345
Pant A–3	13.3	29.8	48.7	30.6	124	266
Parbhat	13.7	28.7	50.4	31.0	109	267
T 21	16.7	34.2	41.2	34.0	105	207
Zn level mean	12.9	33.1	50.9			

C.D. ($P = 0.05$) for differences among means of cultivars, shoots-6 weeks (2.36), leaf (2.38), stem (2.39), pod-hull (1.61) and grain (2.49); means of Zn levels, shoots-6 weeks (1.54), leaf (1.56), stem (1.56), pod-hull (1.05), and grain (1.63); means of cultivar × Zn levels, shoots-6 weeks (4.09), leaf (2.91), stem (4.14), pod-hull (2.78), and grain (4.31).

to 16.7, 4.17 to 5.83, and 9.2 to 16.7 ppm, respectively, in different genotypes (Table 2). The concentration increased with increasing Zn level in all the plant parts in all the genotypes. The increase with 5 ppm Zn over 0 Zn level in shoot at 6 weeks of growth, and in leaf, stem, pod-hull, and grain at maturity ranged from 28 to 248, 28 to 89, 27 to 85, 20 to 142, and 105 to 254 percent, respectively. The corresponding increases with 50 ppm Zn over 0 Zn level were 175 to 400, 121 to 329, 181 to 281, 227 to 701, 207 to 454 percent, respectively. The above results showed that there was a considerable variation in different genotypes with regard to their capacity to exploit soil and applied Zn. However, an interesting observation was that the variability in Zn concentration of most of the varieties decreased after Zn application (Table 2). Further there was considerable build-up in tissue Zn concentration of different genotypes from applied Zn without any relationship with their yield. This indicated that once the minimum requirement of plant is met with, the accumulation of Zn in larger quantities may take place, till it is in excess to cause depression in growth. Several workers[1,6,7,8] in the past also reported accumulation of applied Zn by different crops plants without substantial changes in yield.

A comparison of Zn concentration in different plant parts showed that under Zn deficient conditions, the concentration was much less in pod-hull and the highest concentration was noted in leaf (Table 2). The concentration in stem and grain at maturity, and in shoot at 6 weeks of growth was almost similar (Table 2). The high concentration in grain at 0 Zn level compared to pod-hull showed that a large proportion of Zn absorbed was translocated to grain. There was a considerable accumulation of Zn in grain after Zn application also. The accumulation of Zn in grain might be associated with the products accumulated in it. At high Zn levels, there was relatively less variation in Zn concentration of different plant parts, except pod-hull, and variability among cultivars was also reduced.

Phosphorus concentration

Phosphorus concentration under Zn deficient conditions in plants at six weeks, and in leaf, stem, pod-hull, and grain at maturity ranged from 0.50 to 0.71, 0.18 to 0.31, 0.11 to 0.24, 0.15 to 0.20, and 0.43 to 0.58 percent, respectively (Table 3). A comparison indicated that P concentration in vegetative parts was $\frac{1}{2}$ to less than $\frac{1}{2}$ of that in grain. Also, considerable reduction in the concentration of vegetative parts occurred from six weeks of growth to maturity stages. The products accumulated in grain perhaps required more P. Therefore, the reduction in concentration was partly due to the increase in dry matter yield and partly due to the translocation of P from vegetative parts to grain. The high P in grain also explains for high Zn concentration in it.

The application of Zn decreased P concentration at both the stages of growth

Table 3. Phosphorus concentration in different plant parts of seven cultivars of pigeon pea as affected by Zn levels at two stages of growth

Cultivar	Zn levels (ppm)				% decrease over control	
	0	5	50	Mean	5	50 ppm Zn
P conc. in shoot at 6 weeks, %						
H 72–44	.66	.33	.36	.45	50	45
H 73–20	.50	.27	.30	.36	46	40
Pant A–1	.55	.35	.33	.41	36	40
Pant A–2	.71	.37	.36	.48	48	49
Pant A–3	.54	.30	.34	.39	44	37
Parbhat	.55	.30	.28	.38	45	49
T 21	.68	.34	.32	.45	50	53
Zn level mean	.60	.32	.32			
P conc. in leaf at maturity, %						
H 72–44	.18	.07	.06	.10	62	67
H 73–20	.23	.10	.09	.14	56	61
Pant A–1	.24	.10	.08	.14	58	67
Pant A–2	.31	.11	.09	.17	64	71
Pant A–3	.27	.10	.07	.15	63	74
Parbhat	.21	.11	.11	.14	48	48
T 21	.23	.10	.09	.14	56	61
Zn level mean	.24	.10	.08			
P conc. in stem at maturity, %						
H 72–44	.17	.10	.07	.11	41	59
H 73–20	.19	.12	.12	.14	37	37
Pant A–1	.19	.13	.11	.14	31	42
Pant A–2	.24	.15	.12	.17	37	50
Pant A–3	.11	.09	.07	.09	18	36
Parbhat	.24	.16	.13	.18	33	46
T 21	.20	.06	.04	.10	70	80
Zn level mean	.19	.11	.09			
P conc. in pod-hulls at maturity, %						
H 72–44	.15	.10	.07	.11	33	53
H 73–20	.16	.12	.09	.12	25	44
Pant A–1	.18	.10	.07	.12	44	61
Pant A–2	.20	.13	.10	.14	35	50
Pant A–3	.20	.17	.14	.17	15	30
Parbhat	.15	.11	.09	.12	27	40
T 21	.21	.16	.11	.16	24	48
Zn level mean	.18	.13	.10			

Table 3 (continued)

Cultivar	Zn levels (ppm)				% decrease over control	
	0	5	50	Mean	5	50 ppm Zn
P conc. in grain at maturity, %						
H 72–44	.45	.36	.34	.38	20	24
H 73–20	.43	.30	.30	.34	30	30
Pant A–1	.50	.34	.33	.39	32	34
Pant A–2	.44	.38	.34	.39	14	23
Pant A–3	.45	.34	.31	.37	24	31
Parbhat	.48	.37	.35	.40	23	27
T 21	.58	.30	.23	.37	48	60
Zn level mean	.48	.34	.31			

C.D. (P = 0.05) for differences among means of cultivars, shoot-6 weeks (0.06), leaf (0.03), stem (0.022), husk (.009), and grain (0.02); means of Zn levels, shoot-6 weeks (0.04), leaf (0.02), stem (0.015), pod-hull (0.014), and grain (0.013); means of cultivar × Zn levels, shoot-6 weeks (N.S.), leaf (NS), stem (0.039), pod-hull (NS), and grain (0.034).

in all the plant parts (Table 3). The decrease ranged from 14 to 70 percent depending upon plant parts, stage of growth and Zn level. The relative decrease was more with 5 ppm Zn, and more decrease was noted in leaf than in other plant parts. The decrease with 5 ppm Zn was primarily associated with tremendous increase in yield from Zn application. The decrease in P concentration with Zn was also observed in different crops in the past[6,7,8,9].

Relationship of yield response to P and Zn distribution in different plant parts

An attempt was made to relate the contribution of Zn and P distribution in different above ground plant parts to yield responses. Total and grain yield responses with 5 ppm Zn at maturity were not related to Zn concentration in shoots at 6 weeks of growth ($r = -0.48$ and $-.58$, respectively) and Zn concentration in leaf ($r = -0.62$ and -0.55, respectively) and stem ($r = -.58$ and -0.47, respectively) at maturity. Only stem Zn concentration was significantly negatively related to its own yield ($r = -0.77$*). Otherwise, the Zn concentration in individual plant parts was not related to their yields. However, P/Zn ratio in leaf at maturity was significantly positively related to total yield

* Significant at 5% level of significance.

response (+0.75*). P/Zn ratios in leaf and stem were also significantly positively related to their yield responses (r = +0.89* and +.82*, respectively). Besides, the total Zn uptake in the above ground parts was positively associated with total yield response (r = +0.83*). However, it was not related to grain yield response (r = 0.57).

These relationships indicated that a part of the variability among cultivars to Zn response was associated with their capacity to exploit soil Zn. However, the maintenance of a proper P/Zn balance in metabolically active plant parts, such as leaf, for normal growth was also clearly evidenced. The association of stem yield with the maintenance of proper P/Zn balance in it, is also an interesting observation. Cultivars which maintained narrower P/Zn ratio responded less to applied Zn. These results showed that Zn response pattern in pigeon pea cultivars was partly associated with their capacity to accumulate and distribute P in different plant parts as reported by Ambler and Brown[1] and Safaya and Singh[6] by using two cultivars of soybean and cowpea, respectively. However, unlike their observations attributing differential susceptibility to P/Zn balance only, the present investigation indicated that in pegeon pea the efficiency of different genotypes to exploit soil Zn and its translocation to different plant parts also determined their capacity to overcome adverse effect to Zn-stress conditions. Therefore, behaviour of pigeon pea genotypes was partly similar to wheat and corn as reported by Shukla and Hans Raj[7,8].

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