International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 18, 2018, pp.-7241-7245
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

NODULATION AND NUTRIENT UPTAKE IN GRAIN COWPEA (*Vigna unguiculata* L. Walp) UNDER VARYING LEVELS OF PHOSPHORUS, POTASSIUM AND ZINC

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Received: September 01, 2018; Revised: September 10, 2018; Accepted: September 11, 2018; Published: September 15, 2018

Abstract: A field experiment was conducted in a phosphorus rich soil in the southern district of Kerala to assess the effect of varying levels of P, K and Zn on the nodulation and nutrient uptake in grain cowpea during January to March 2018. The treatments included two levels of P, three levels of Zn and two levels of K laid out in factorial RBD with three replications. The results revealed significantly superior nodule weights for the highest doses of P, K and Zn for main and interaction effects. Nutrient uptake varied and the highest P, K and foliar Zn recorded significantly higher uptake values of P, K and Zn while N uptake was maximum for foliar Zn and no P application. Zn x K recorded a positive interaction for nutrient uptake while P x Zn showed negative interaction in K uptake. Nutrient (N, P, Zn) uptake were higher in grain cowpea grown in high phosphorus soils through foliar application of Zn as $ZnSO_4$ @ 0.025% (at branching and flowering) along with 10 kg K_2O ha^{-1}.

Keywords: Phosphorus, Zinc, Nodulation

Citation: Anjaly V. and Sheeba Rebecca Isaac (2018) Nodulation and Nutrient Uptake in Grain Cowpea (*Vigna unguiculata* L. Walp) under Varying Levels of Phosphorus, Potassium and Zinc. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 18, pp.- 7241-7245.

Introduction

Cowpea (*Vigna unguiculata* L. walp) is one of the most important short duration pulse crops of Kerala. It is assumed to be the principal ancient pulse crop of India and is characteristically known for wide geographic distribution and adaptation across soil types, soil inputs and agroclimatological zones [1]. Among the different essential elements, phosphorus (P), potassium (K) and zinc (Zn) have specific roles in legumes. Phosphorus is one of the pioneer nutrients essential for legumes to stimulate root growth, nodule formation and to improve Rhizobium - legume symbiosis [2]. The available P status in the southern laterites of Kerala is reported as high [3] and hence should have a positive influence on the growth and yield of cowpea. But, a negative interaction has been identified to exist between P and the micro nutrient Zn [4,5]. The high P status leads to reduced uptake and utilization of Zn which is also important for growth and productivity in cowpea. Increasing levels of K can reduce the severity of P induced Zn deficiency in plants [7]. Nutrient management should thus emphasise on balanced nutrition, and hence, taking into account the possible interactions that can occur, a study was undertaken to evaluate the effect of different levels of P, K and Zn on nodulation and nutrient uptake in grain cowpea.

Materials and Methods

The field experiment was conducted in farmer's field, Palappur, Kalliyoor Panchayath, Thiruvananthapuram during January to March 2018. The site situated at 8.43°N latitude, 76.99°E longitude and at an altitude 29 m above mean sea level, is characterised by humid tropical climate. The soil was sandy clay loam with pH of 5.77 and the organic carbon content, available N, P, K and Zn were 1.29%, 112.49 kg ha^{-1}, 98.62 kg ha^{-1}, 308 kg ha^{-1} and 0.91 mg kg^{-1}, respectively. Grain cowpea (*Vigna unguiculata* (L.) Walp.) variety Shubra, was raised in plots of size 2.5 m x 1.5 m at a spacing of 25 cm x 15 cm. The 2 x 3 x 2 factorial experiment was laid out in randomized block design with three replications and 12 treatment combinations. The treatments consisted of two levels of P (p_0 - 0 kg ha^{-1}, p_1 -7.5 kg ha^{-1}), three levels of Zn (z_0 - 0 kg ha^{-1}, z_1 – 2.5 kg ha^{-1} as $ZnSO_4$, z_2 - 0.025% $ZnSO_4$ as foliar at branching and flowering) and two levels of K (k_1-10 kg ha^{-1}, k_2 - 20 kg ha^{-1}). Lime, FYM and N were applied as per package of practices recommendations [8]. Three plants were carefully uprooted at vegetative (30DAS) and flowering stages and soil mass embodying the roots of the plants was washed off in running water. The nodules were separated from the roots and weighed to record the nodule weight plant^{-1}. The mean value was recorded on fresh weight basis. The N,P,K and Zn contents in plant at vegetative, flowering and harvest were estimated as per standard procedures [9]. Nutrient contents were multiplied with respective dry matter production to compute the uptake and expressed in kg ha^{-1}. The data were statistically analysed using the F-test [10].

Results

Nodule weight increased with cowpea growth, higher nodule weights being observed at the flowering stage irrespective of the treatments [Table-1a]. Phosphorus levels had a significant influence on the nodule weight at vegetative and flowering stage. Phosphorus application @ 7.5 kg ha^{-1} resulted in higher nodule weights (0.36 and 3.26 g plant^{-1}), at vegetative and flowering stage, respectively, compared to zero P. This brings to light the positive influence of P on nodulation and nitrogen fixation in cowpea. Soil application of Zn exhibited significantly higher nodule weights, at par with the foliar application. The better nodule weight in soil application compared to foliar application of Zn could be ascribed to the better availability of Zn in roots when applied to the soil. This agreed with the findings of Todawat (2017) [11]. Potassium also exerted significant influence on nodule weights and this was superior with the higher dose application (k_2). Srinivasarao *et al.* (2003) reported the significant role of K in enhancement of biological nitrogen fixation and protein content of pulse grains [10]. The individual effects were reflected in the interaction also [Table-1b]. Combined application of 7.5 kg P_2O_5 ha^{-1}, 2.5 kg ha^{-1} Zn and 20 kg K_2O ha^{-1} in soil *i.e.*, $p_1z_1k_2$ recorded significantly higher nodule weights of 0.52 and 4.97g plant^{-1}, at vegetative and flowering stage, respectively [Fig-1].

Table-1a Effect of levels of P, Zn and K on growth attributes of cowpea

Treatments	Nodule weight(g)	
	Vegetative	Flowering
Levels of Phosphorus		
p_0 (0 kg ha^{-1})	0.32	2.79
p_1 (7.5 kg ha^{-1})	0.36	3.26
SEm (±)	0.01	0.08
CD(0.05)	0.023	0.222
Levels of Zinc		
z_0 (0 kg ha^{-1})	0.31	2.71
z_1 (2.5 kg ha^{-1})	0.37	3.27
z_2 (0.025% foliar)	0.35	3.1
SEm (±)	0.01	0.09
CD (0.05)	0.029	0.272
Levels of Potassium		
k_1 (10 kg ha^{-1})	0.33	2.87
k_2 (20 kg ha^{-1})	0.36	3.18
SEm (±)	0.01	0.08
CD (0.05)	0.023	0.222

Table-1b Interaction effects on nodule weights in cowpea

Interactions	Days to 50% flowering	Nodule weight(g plant^{-1})	
		Vegetative	Flowering
P x Zn interaction			
p_0z_0	47.5	0.38	3.41
p_0z_1	44.8	0.27	2.19
p_0z_2	39.3	0.32	2.77
p_1z_0	47.3	0.23	2.00
p_1z_1	47.1	0.47	4.35
p_1z_2	40.3	0.39	3.42
SEm (±)	0.77	0.01	0.13
CD(0.05)	NS	0.041	0.384
P x K interaction			
p_0k_1	43.0	0.28	2.39
p_0k_2	44.7	0.37	3.19
p_1k_1	44.2	0.38	3.34
p_1k_2	45.6	0.35	3.17
SEm (±)	0.63	0.01	0.11
CD(0.05)	NS	0.033	0.314
Zn x K interaction			
z_0k_1	47.6	0.33	2.87
z_0k_2	47.1	0.28	2.54
z_1k_1	45.6	0.31	2.73
z_1k_2	46.3	0.42	3.81
z_2k_1	37.5	0.35	3.00
z_2k_2	42.1	0.36	3.20
SEm (±)	0.77	0.01	0.13
CD (0.05)	2.271	0.041	0.384

Table-2a Effect of levels of P, Zn and K on P and N uptake in cowpea, kg ha^{-1}

Treatments	N uptake				P uptake			
	Vegetative	Flowering	Harvest		Vegetative	Flowering	Harvest	
			Bhusa	Pod			Bhusa	Pod
Levels of phosphorus								
p_0 (P @ 0 kg ha^{-1})	5.3	51.0	107.4	74.3	0.5	9.2	7.8	13.4
p_1 (P @ 7.5 kg ha^{-1})	5.3	51.3	96.0	71.2	0.7	11.1	8.7	12.3
SEm (±)	0.5	1.9	2.6	2.3	0.1	0.4	0.6	0.7
CD(0.05)	NS	NS	0.748	NS	0.19	1.21	NS	NS
Levels of Zinc								
z_0 (Zn @ 0 kg ha^{-1})	6.2	47.0	97.3	64.8	0.7	9.4	7.8	11.3
z_1 ($ZnSO_4$ @ 2.5 kg ha^{-1})	4.7	56.5	96.9	64.2	0.6	11.3	9.5	13.7
z_2 ($ZnSO_4$ @ 0.025% foliar)	5.0	49.9	110.9	89.4	0.5	9.7	7.6	13.5
SEm (±)	0.06	2.4	3.1	2.8	0.1	0.5	0.8	0.8
CD (0.05)	NS	6.89	9.17	8.32	NS	1.49	NS	NS
Levels of Potassium								
k_1 (K@ 10kg ha^{-1})	5.9	50.1	101.9	74.6	0.6	9.8	7.5	13.7
k_2 (K@ 20 kg ha^{-1})	4.7	52.2	101.5	70.9	0.5	10.4	9.1	12.0
SEm (±)	0.5	1.9	2.6	3.1	0.1	0.4	0.6	0.7
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table-2b Effect of P x Zn, x K and Zn x K interactions on N and P uptake in cowpea, kg ha^{-1}

Interactions	N uptake				P uptake			
	Vegetative	Flowering	Harvest		Vegetative	Flowering	Harvest	
			Bhusa	Pod			Bhusa	Pod
P x Zn interaction								
p_0z_0	5.7	45.4	101.1	64.2	0.5	8.4	6.7	10.5
p_0z_1	4.6	59.8	100.7	62.0	0.5	10.7	9.2	14.8
p_0z_2	5.7	47.7	120.4	96.8	0.5	8.4	7.7	14.8
p_1z_0	6.8	48.5	93.5	65.3	0.9	10.4	9.0	12.1
p_1z_1	4.8	53.2	93.1	66.4	0.7	11.9	9.7	12.7
p_1z_2	4.2	52.1	101.4	81.9	0.5	11.0	7.5	12.1
SEm (±)	0.8	3.3	4.4	4.0	0.1	0.7	0.9	1.2
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
P x K interaction								
p_0k_1	6.6	50.8	107.4	76.8	0.6	9.2	6.5	14.0
p_0k_2	4.0	51.1	107.4	71.8	0.4	9.1	9.2	12.7
p_1k_1	5.2	49.4	96.5	72.4	0.7	10.4	8.5	13.3
p_1k_2	5.3	53.2	95.5	70.0	0.7	11.7	8.9	11.3
SEm (±)	0.7	2.7	3.6	3.3	0.1	0.6	1.1	1.0
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Zn x K interaction								
z_0k_1	6.2	45.8	91.0	62.3	0.7	9.2	6.9	11.6
z_0k_2	6.2	48.1	103.5	67.2	0.7	9.7	8.7	11.0
z_1k_1	5.2	48.6	94.1	64.7	0.7	10.1	7.6	15.5
z_1k_2	4.2	64.5	99.7	63.7	0.5	12.4	11.3	12.0
z_2k_1	6.3	55.9	120.6	96.9	0.6	10.2	8.0	13.9
z_2k_2	3.6	43.9	101.2	81.8	0.4	9.1	7.2	13.0
SEm (±)	0.8	3.3	4.4	4.0	0.1	0.7	0.9	1.2
CD (0.05)	NS	9.74	1.296	NS	NS	NS	NS	NS

Table-2c Effect of P x Zn x K interaction on N and P uptake in cowpea, kg ha^{-1}

Treatment combinations	N uptake				P uptake			
	Vegetative	Flowering	Harvest		Vegetative	Flowering	Harvest	
			Bhusa	Pod		Bhusa	Bhusa	Pod
$p_0z_0k_1$	6.6	44.7	91.7	57.2	0.6	9.3	5.3	10.9
$p_0z_0k_2$	4.7	46.2	110.4	71.2	0.4	7.6	8.1	10.1
$p_0z_1k_1$	5.0	56.5	91.7	60.8	0.6	9.6	6.7	15.9
$p_0z_1k_2$	4.1	63.1	109.8	63.2	0.4	11.8	11.7	13.7
$p_0z_2k_1$	8.2	51.3	138.7	112.4	0.7	8.9	7.4	15.3
$p_0z_2k_2$	3.2	44.1	102.2	81.1	0.3	7.9	7.9	14.2
$p_1z_0k_1$	5.9	47.0	90.3	67.4	0.7	9.1	8.6	12.4
$p_1z_0k_2$	7.7	50.0	96.7	63.3	1.0	11.8	9.3	11.9
$p_1z_1k_1$	5.3	40.6	96.5	68.5	0.8	10.7	8.4	15.1
$p_1z_1k_2$	4.3	65.9	89.6	64.2	0.6	13.1	11.0	10.2
$p_1z_2k_1$	4.4	60.5	102.6	81.4	0.5	11.6	8.6	12.5
$p_1z_2k_2$	4.0	43.7	100.2	82.5	0.5	10.3	6.4	11.7
SEm (±)	1.2	4.7	8.5	5.7	0.2	1.0	1.5	1.7
CD (0.05)	NS	NS	24.92	16.64	NS	NS	NS	NS

Table-3a Effect of levels of P, Zn and K on K and Zn uptake in cowpea, kg ha^{-1}

Treatments	K uptake				Zn uptake			
	Vegetative	Flowering	Harvest		Vegetative *(x 10^{-2})	Flowering *(x 10^{-2})	Harvest *(x 10^{-2})	
			Bhusa	Pod			Bhusa	Pod
Levels of phosphorus								
p_0 (0 kg ha^{-1})	3.0	42.9	78.8	76.9	0.295(1.72)	5.79(7.61)	3.84(6.20)	4.28(6.55)
p_1 (7.5 kg ha^{-1})	2.7	43.6	69.4	72.4	0.259(1.61)	6.14(7.84)	3.78(6.15)	3.52(5.94)
SEm (±)	0.3	2.5	3.4	3.7	0.11	0.38	0.25	0.25
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Levels of Zinc								
z_0 (0 kg ha^{-1})	3.0	44.2	71.2	75.0	0.371(1.93)	3.99(6.32)	2.32(4.82)	3.08(5.55)
z_1 (2.5 kg ha^{-1})	2.7	46.5	82.7	70.5	0.223(1.49)	5.01(7.08)	4.05(6.37)	2.69(5.19)
z_2 (0.025% foliar)	2.9	39.1	68.3	78.6	0.247(1.57)	9.56(9.78)	5.38(7.34)	6.37(7.99)
SEm (±)	0.4	3.1	4.2	4.6	0.14	0.47	0.31	0.30
CD (0.05)	NS	NS	NS	NS	NS	1.374	0.904	0.885
Levels of Potassium								
k_1 (10kg ha^{-1})	3.4	32.2	67.1	61.5	0.354(1.88)	6.50(8.07)	3.92(6.26)	3.92(6.26)
k_2 (20 kg ha^{-1})	2.3	54.3	81.0	87.9	0.209(1.45)	5.45(7.39)	3.70(6.09)	3.87(6.22)
SEm (±)	0.3	2.5	3.4	3.7	0.11	0.38	0.25	0.25
CD(0.05)	0.86	7.3	10.07	10.96	0.322	NS	NS	NS

Table-3b Interaction effects on K and Zn uptake in cowpea, kg ha^{-1}

Interactions	K uptake				Zn uptake			
	Vegetative	Flowering	Harvest		Vegetative *(x 10^{-2})	Flowering *(x 10^{-2})	*Harvest(x 10^{-2})	
			Bhusa	Pod			Bhusa	Pod
P x Zn interaction								
p_0z_0	2.8	42.0	65.7	78.2	0.450 (2.12)	3.17 (5.64)	2.68 (5.18)	3.21 (5.67)
p_0z_1	2.7	50.8	99.3	71.6	0.246 (1.57)	6.43 (8.02)	4.37 (6.61)	2.94 (5.42)
p_0z_2	3.4	35.7	71.3	81.0	0.215 (1.47)	8.43 (9.18)	4.64 (6.81)	7.30 (8.55)
p_1z_0	3.2	46.3	76.6	71.9	0.298 (1.73)	4.89 (7.00)	1.99 (4.47)	2.95 (5.44)
p_1z_1	2.7	42.1	66.2	69.3	0.201 (1.42)	3.77 (6.14)	3.74 (6.12)	2.46 (4.96)
p_1z_2	2.3	42.5	65.4	76.1	0.283 (1.68)	10.77 (10.38)	6.18 (7.87)	5.51 (7.43)
SEm (±)	0.5	4.4	6.0	6.5	0.19	0.66	0.44	0.43
CD(0.05)	NS	NS	17.44	NS	NS	1.943	NS	NS
P x K interaction								
p_0k_1	3.9	29.9	68.8	62.8	0.392 (1.98)	8.51 (9.23)	3.73 (6.11)	4.63 (6.807)
p_0k_2	2.0	55.8	88.7	91.1	0.213 (1.46)	3.60 (6.00)	3.95 (6.29)	3.94 (6.284)
p_1k_1	2.8	34.5	65.3	60.2	0.318 (1.78)	4.77 (6.91)	4.11 (6.42)	3.26 (5.718)
p_1k_2	2.6	52.8	73.4	84.6	0.206 (1.43)	7.69 (8.77)	3.46 (5.89)	3.79 (6.164)
SEm (±)	0.4	3.6	4.9	5.3	0.16	0.54	0.36	0.35
CD(0.05)	NS	NS	NS	NS	NS	1.586	NS	NS
Zn x K interaction								
z_0k_1	3.3	30.4	65.6	56.5	0.436 (2.09)	2.74 (5.24)	3.28 (5.74)	3.24 (5.70)
z_0k_2	2.7	58.0	76.7	93.6	0.310 (1.76)	5.47 (7.40)	1.53 (3.91)	2.92 (5.41)
z_1k_1	3.1	29.7	69.7	62.2	0.269 (1.64)	6.95 (8.34)	2.71 (5.22)	2.38 (4.89)
z_1k_2	2.3	63.3	95.7	78.8	0.181 (1.35)	3.38 (5.82)	5.65 (7.52)	3.02 (5.50)
z_2k_1	3.7	36.5	65.9	65.9	0.366 (1.91)	11.27(10.62)	6.14 (7.84)	6.72 (8.20)
z_2k_2	2.1	41.7	70.7	91.3	0.152 (1.23)	7.99 (8.94)	4.67 (6.84)	6.03 (7.77)
SEm (±)	0.5	4.4	6.0	6.5	0.19	0.66	0.44	0.43
CD (0.05)	NS	12.8	NS	NS	NS	1.943	1.278	NS

*Square Root Transformation, Transformed values in parentheses

Table-3c Effect of P x Zn x K interaction on K uptake by cowpea, kg ha^{-1}

Treatment combinations	K uptake				Zn uptake			
	Vegetative	Flowering	Harvest		Vegetative *(x 10^{-2})	Flowering *(x 10^{-2})	Harvest *(x 10^{-2})	
			Bhusa	Pod			Bhusa	Pod
$p_0z_0k_1$	3.4	29.8	62.1	60.8	0.551(2.35)	2.40(4.81)	3.32(5.77)	3.22(5.68)
$p_0z_0k_2$	2.2	54.3	69.3	95.6	0.360(1.90)	4.19(6.47)	2.10(4.59)	3.19(5.66)
$p_0z_1k_1$	3.2	31.3	79.6	60.9	0.270(1.64)	12.73(11.29)	3.21(5.67)	2.43(4.94)
$p_0z_1k_2$	2.1	70.4	119.0	82.4	0.224(1.50)	2.26(4.76)	5.70(7.55)	3.49(5.91)
$p_0z_2k_1$	5.0	28.7	64.8	66.6	0.379(1.95)	13.41(11.58)	4.75(6.89)	9.61(9.81)
$p_0z_2k_2$	1.8	42.8	77.7	95.4	0.097(0.98)	4.60(6.78)	4.53(6.73)	5.31(7.29)
$p_1z_0k_1$	3.2	30.9	69.0	52.2	0.335(1.83)	3.21(5.67)	3.25(5.70)	3.27(5.72)
$p_1z_0k_2$	3.2	61.6	84.2	91.6	0.264(1.63)	6.93(8.33)	1.04(3.24)	2.65(5.15)
$p_1z_1k_1$	2.9	28.0	59.9	63.5	0.269(1.64)	2.91(5.40)	2.26(4.76)	2.33(4.83)
$p_1z_1k_2$	2.4	56.2	72.4	75.1	0.143(1.19)	4.73(6.88)	5.60(7.48)	2.58(5.09)
$p_1z_2k_1$	2.4	44.4	67.1	65.1	0.353(1.88)	9.32(9.66)	7.72(8.79)	4.35(6.60)
$p_1z_2k_2$	2.3	40.6	63.6	87.2	0.220(1.48)	12.32(11.10)	4.82(6.94)	6.80(8.25)
SEm (±)	0.7	6.2	8.4	9.2	0.27	0.94	0.62	0.60
CD (0.05)	NS	NS	NS	NS	NS	2.747	NS	1.769

*Square Root Transformation, Transformed values in parentheses

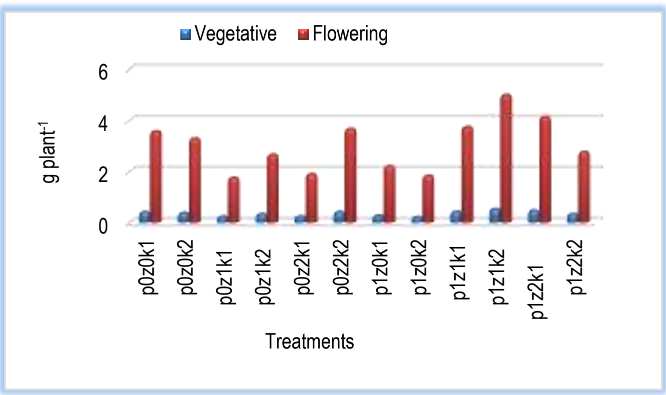

Fig-1 Effect of P x Zn x K interaction on nodule weight in cowpea (CD- 0.057 and 0.544)

It is also pointed out that the response to the fertilisers through nodule weight increase might be due the lower initial nitrogen status in soil. Nutrient uptake recorded at different stages revealed increased uptake with the growth of the plant [Table-2]. The levels of P significantly influenced N uptake at harvest (107.4 kg ha^{-1}) and P uptake at vegetative and flowering stages (0.7 and 11.1 kg ha^{-1} respectively) and the latter were superior at the higher level of P [Table-2a]. Zinc application recorded superior N, P and Zn uptake, while K was found to influence K uptake alone. In general, the application of the nutrient input recorded greater removal of the nutrient compared to the treatments of no application. This could be attributed to the better biomass production due to a balanced supply of the major nutrients through fertilizers. The increased nodulation with the higher levels of nutrients would have contributed to the higher N uptake in the respective treatments. Among interactions, Zn x K recorded significant variations in N, K and Zn uptake [Table-2b] and [Table-3b]. A positive interaction between Zn and K was observed, with nutrient uptake increasing with the application of nutrients, the highest being for the foliar Zn combinations owing to increased absorption, reduced losses and hence better utilisation of Zn for dry matter production compared to soil application. The expected P x Zn antagonistic interaction was observed in K and Zn uptake and in former, a significant decline was recorded in P application treatment when Zn was applied to soil (p_1z_1).

With respect to Zn uptake, the uptake was less in p_1z_1 (0.377 kg ha^{-1}) compared to p_0z_1 (0.634 kg ha^{-1}). It is interpreted that due to the increased P uptake [Table-3a], Zn absorption and translocation would have been interrupted as reported by Oseni (2009) [12] and thus may not have become available for utilisation in the plants. When the interactions of the three nutrients were considered [Table-2c] and [Table-3c], the combination $p_0z_2k_1$ recorded significantly superior uptake in N and Zn. This may be attributed to the higher dry matter production in the plants as the three nutrients were available to the plants in a balanced combination. The soil status was initially high in available P and the crop would have met its requirement from soil along with the foliar Zn and soil K applied. The higher K uptake with K application could be ascribed to luxury consumption of K, phenomenon reported when crops are grown in soils rich in K or supplied through fertilisers. The response to the 10 kg K_2O application even when the soil status was high the latter might be accounted as due the leaching losses related to the nutrient in soil.

Conclusion

The results of the study revealed that higher nodulation was observed with increased doses of P,K and Zn whereas nutrient (N and Zn) uptake were higher in grain cowpea grown in high phosphorus soils in a nutrient package of foliar application of $ZnSO_4$ @ 0.025% twice at branching and flowering along with 10 kg K_2O ha^{-1}.

Application of research: Zinc is highly essential for the growth and nodulation of legumes. Research is focused on arriving at a nutrient dose that can make available Zinc even in high Phosphorus soils.

Research Category: Field crop research

Abbreviations: N- Nitrogen, P- Phosphorus, K- Potassium, ha - hectare

Acknowledgement / Funding: Author thankful to College of Agriculture, Vellayani, Thiruvananthapuram 695 522, Kerala Agricultural University, Thrissur, 680656, Kerala India

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Research project name: MSc Thesis - Nutrient optimization for grain cowpea (*Vigna unguiculata* L Walp) in high phosphorus soils

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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