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Influence of nodulation on growth, and yield performance of cowpea varieties

Preeti Massey, PK Singh, MK Nautiyal and YV Singh

Abstract
The experiment was conducted at Seed Production centre, G.B. Pant University of Agriculture & Technology, Pantnagar in Summer 2018 cropping season. Experimental material consisted of 26 cowpea varieties which were grown in three replications in a randomized complete block design. Each experimental plot measures 1.8 m × 4.0 m (7.2 m2). Two seeds were sown in each hole for each treatment. Five plants from the central rows of each plot were randomly selected for measuring days to 50% flowering plant height, no. of nodules per plant, nodulation score, thrip score and dry weight. Then the average values of these plants were recorded. Nodulation assessment was undertaken at mid (50%) flowering stage by carefully uprooting five plants randomly from each plot. The adhering soil was carefully washed from the roots. The nodules from each plant were counted and scoring was done and their average was taken for plots. The results obtained in this study have shown that nodulation is a very important trait of cowpea varieties and it affects the grain yield of cowpea varieties. The higher plant growth and increased nodulation in plants translated into increased grain yield. Based on the findings of the current study the use of cow pea variety CST-6, CST-13 and CST-4 could be recommended for enhanced growth and yield performance of cowpea.

Keywords: Nodulation, cowpea, thrips score, rhizobium

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp] is a major grain legume grown in semi-arid regions of Sub-Saharan Africa. It is a major source of protein and a cheap source of quality protein for both rural and urban dwellers in Africa (Ajeigbe *et al*., 2012; Dube and Fanadzo, 2013) [2, 3]. Cowpea leaves and green pods are consumed as vegetable and the dried grain is used in many different food preparations. Grain legumes play a vital role in the lives of millions of people in developing countries to achieve food and nutritional security. They complement staple low-protein cereal crops as a source of protein and minerals (Gharti *et al*., 2014) [21]. Legume crops are also valued for their ability to fix atmospheric nitrogen into the soil and play an important role as a rotation crop with cereals and vegetable crops (Jensen *et al*., 2012; Biswas and Gresshoff, 2014; Stagnari *et al*., 2017) [22, 23, 24]. Legumes also serve as a feed crop in many farming systems and are also grown to supplement farmers' incomes (Muli and Saha, 2002; Voisin *et al*., 2013) [25, 27]. Protein content of cowpea leaves range from 27 to 43% and protein concentration of the dry grain range from 21 to 33% (Ahenkora *et al*., 1998; Ddamulira *et al*., 2015; Abudulai *et al*., 2016) [5, 6, 1]. Cowpea is also an important component of the traditional cropping systems because it fixes atmospheric nitrogen and contributes to soil fertility improvement particularly in smallholder farming systems where little or no fertilizer is used. It is drought tolerant and adapted to stressful environments where many crops fail to grow well and the crop also improves soil fertility by fixing the atmospheric nitrogen. (Bisikwa *et al*., 2014; Ddamulira *et al*., 2015) [9, 5]. The Leguminosae are unique in their ability to form N2-fixing symbioses with members of the Rhizobiaceae (or rhizobia). Inside root nodules these rhizobial bacteria are able to reduce atmospheric N2 into ammonia by the nitrogenase enzyme. In many parts of the world (especially West Africa), soils are experiencing a decline in nitrogen status which is a major determinant of food production [4]. In rhizobium-cowpea symbiosis, soil fertility status and fertilizer, in the case of external N application, affect both rhizobium and cowpea. Cowpea is also affected when soil N is low and no rhizobium is present. It has been found that high concentration of nitrate (NO3) in waste effluents and high air temperature can inhibit nodulation and N2 fixation in symbiotic legumes [8, 9]. These findings suggest that while soil low in N can negatively affect the growth of cowpea, soil high in N or amended by N fertilizer, at certain rates, can also have a negative impact on the crop by reducing the N2 fixation Potential. It is therefore important to determine the level of N above which nodulation and nitrogen fixation of rhizobia-inoculated cowpea can be negatively affected. Many leguminous plants are able to establish symbiosis with a variety of bacterial species of the phylum Proteobacteria, which are collectively referred to as rhizobia. This symbiosis is characterized by the formation of nodules on the roots and/or stems of plants, where the bacteria encounter optimal conditions for biological nitrogen fixation (BNF; Graham, 2008). The formation of these nodules is a highly regulated process, the success of which depends on the exchange of specific signaling molecules between the micro and the macrosymbiont (Oldroyd *et al*., 2011). Bacteria capable of inducing nitrogen-fixing nodules on the roots of leguminous plants are found among the Alphaproteo bacteria e.g., *Rhizobium*, *Bradyrhizobium*, *Ochrobactrum*, *Ensifer*, *Phyllobacterium*, *Mesorhizobium*, *Devosia*, *Azorhizobium*, *Allorhizobium*, *Shinella*, *Methylobacterium*, and *Microvirga*) and Betaproteobacteria (genera *Burkholderia* and *Cupriavidus*; Gyaneshwar *et al*., 2011; Remigi *et al*., 2016). It is estimated that cowpea can fix up to 200 kg N /ha (Dakora *et al*., 1987; Giller, 2001; Rusinamhodzi *et al*., 2006; Adjei-Nsiah *et al*., 2008) [10, 11, 12, 13] and can leave a positive soilN balance of up to 92 kg/ ha (Chikowo *et al*., 2004; Rusinamhodzi *et al*., 2006) [12, 11]. Until recently, it was assumed that indigenous Bradyrhizobium spp. that effectively nodulate cowpea was abundantly present in tropical soils (Caldwell and Vest, 1968; Singleton *et al*., 1992; Kimiti and Odee, 2010) [16, 17, 18] and therefore inoculation was not necessary. A field experiment was conducted at Seed Production Centre, G.B.P.U.A.&T., Pantnagar to evaluate the nodulation pattern and thrip resistance in cowpea varieties. The treatment consisted of 26 cowpea varieties. The experiment was carried out using a randomized complete block design with three replications. The results revealed marked varietal differences in plant growth, nodulation, yield and yield components. It could, thus, be deduced that nodulation markedly increases the productivity of the crop in the region. Thus, the development of new varieties having incresed nodulation will enhance yield and mineral nutrition of grain and it is imperative to achieve food and nutritional security in the country. Therefore, the aim of this study was to evaluate the effect of *nodulation* on plant growth, and yield of cowpea varieties grown at Pantnagar.

Materials and methods

The experiment was conducted at Seed Production centre, G.B. Pant University of Agriculture & Technology, Pantnagar in Summer 2018 cropping season. Experimental material consisted of 26 cowpea varieties which were grown in three replications in a randomized complete block design. Each experimental plot measures 1.8 m × 4.0 m (7.2 m2). Two seeds were sown in each hole for each treatment. Five plants from the central rows of each plot were randomly selected for measuring days to 50% flowering plant height, no. of nodules per plant, nodulation score, thrip score and dry weight. Then the average values of these plants were recorded. Nodulation assessment was undertaken at mid (50%) flowering stage by carefully uprooting five plants randomly from each plot. The adhering soil was carefully washed from the roots. The nodules from each plant were counted and scoring was done and their average was taken for plots.

Table 1: Table showing the mean values of different traits studied.

S. No.	Varieties	50% Flow.	Maturity	Thrips	Pl.Ht.	Dry Wt.	Nod.	yield (qtl/hac)
1	CST-1	54.33	76.00	3.00	24.67	25.45	2.47	13.89
2	CST-2	50.67	71.67	2.50	27.00	19.10	2.03	15.69
3	CST-3	46.33	73.67	3.67	26.67	26.31	1.53	9.86
4	CST-4	51.00	75.00	3.00	26.33	42.16	2.27	18.29
5	CST-5	40.67	71.67	2.50	28.33	28.70	3.20	12.78
6	CST-6	51.33	75.33	2.17	27.33	33.83	3.00	24.44
7	CST-7	54.33	83.00	1.00	34.33	29.88	3.20	6.94
8	CST-8	54.00	75.00	3.17	27.00	26.99	2.53	10.00
9	CST-9	48.33	72.33	4.00	30.33	18.94	2.13	9.63
10	CST-10	50.00	75.00	3.83	29.33	16.48	2.20	10.00
11	CST-11	48.33	72.67	4.00	30.33	17.83	3.23	10.09
12	CST-12	53.33	76.00	4.33	22.00	30.17	2.57	12.87
13	CST-13	50.33	72.33	2.67	26.00	43.45	2.47	21.57
14	CST-14	53.33	75.00	2.17	30.67	28.86	1.90	16.20
15	CST-15	46.00	74.33	4.33	29.67	26.98	2.40	8.24
16	CST-16	48.33	73.33	3.50	27.33	25.39	2.27	10.46
17	CST-17	47.67	74.33	4.00	28.67	26.04	2.83	8.52
18	PL-1	56.00	77.00	4.00	25.67	26.03	2.93	1.84
19	PL-2	50.67	76.67	3.00	26.33	29.73	2.40	4.69
20	PL-3	50.67	72.33	2.00	32.33	33.40	2.87	10.09
21	PL-4	41.33	71.33	3.50	19.33	33.70	1.67	3.21
22	PL-5	49.67	75.33	2.67	23.67	41.62	2.00	5.14
24	GCP-232	51.67	75.67	1.50	28.00	27.39	2.70	10.78
25	GCP-234	50.67	76.67	2.50	26.67	24.93	3.20	9.32
26	GCP-297	52.00	74.33	2.17	25.00	35.34	2.23	7.94
	Gm	50.30	74.64	2.94	27.55	28.76	2.50	10.89
	cd at 5%	3.19	2.33	0.87	6.28	4.00	0.79	3.50
	cv	3.87	1.90	18.16	13.91	8.48	19.29	19.56

Anova

	df	Plant Height	Dry wt. (gm)	Nodulation	50 % flowering (days)	Thrips Score	Maturity (days)	Yield (quintals/hac)
rep	2	3.64	11.78	0.28	12.03	2.33	3.04	41.12
treat	24*	30.23 **	150.75 **	0.7**	41.09**	2.44**	17.66**	84.73
error	48	13.69	5.85	0.23	3.92	0.29	2.02	4.54
total	74	18.78	53	0.38	16.2	0.98	7.12	31.54
cd at 5%		6.07	3.97	0.80	3.25	0.89	2.33	3.50
cv		13.54	8.41	19.59	3.96	18.03	1.90	19.56

Correlation

	Plant Height	Dry wt. (gm)	Nodulation	50 % flowering (days)	Thrips Score	Maturity (days)	Yield (quintals/hac)
Plant Height		-0.233 *	-0.230 *	0.141	-0.206	0.107	-0.009
Dry wt. (gm)			-0.106	0.046	-0.317 **	0.052	0.223
Nodulation				0.130	-0.192	0.218	0.026
50 % flowering (days)					-0.220	0.491**	0.120
Thrips Score						-0.311**	-0.195
Maturity (days)							-0.163
Yield (quintals/hac)							

S. No.	Varieties	50% Flow.	Maturity	Thrips	Pl.Ht.	Dry Wt.	Nod.
1	CST-1	54.33		3.00	24.67	25.45	2.47
2	CST-2	50.67		2.50	27.00	19.10	2.03
3	CST-3	46.33		3.67	26.67	26.31	1.53
4	CST-4	51.00		3.00	26.33	42.16	2.27
5	CST-5	40.67		2.50	28.33	28.70	3.20
6	CST-6	51.33		2.17	27.33	33.83	3.00
7	CST-7	54.33		1.00	34.33	29.88	3.20
8	CST-8	54.00		3.17	27.00	26.99	2.53
9	CST-9	48.33		4.00	30.33	18.94	2.13
10	CST-10	50.00		3.83	29.33	16.48	2.20
11	CST-11	48.33		4.00	30.33	17.83	3.23
12	CST-12	53.33		4.33	22.00	30.17	2.57
13	CST-13	50.33		2.67	26.00	43.45	2.47
14	CST-14	53.33		2.17	30.67	28.86	1.90
15	CST-15	46.00		4.33	29.67	26.98	2.40
16	CST-16	48.33		3.50	27.33	25.39	2.27
17	CST-17	47.67		4.00	28.67	26.04	2.83
18	PL-1	56.00		4.00	25.67	26.03	2.93
19	PL-2	50.67		3.00	26.33	29.73	2.40
20	PL-3	50.67		2.00	32.33	33.40	2.87
21	PL-4	41.33		3.50	19.33	33.70	1.67
22	PL-5	49.67		2.67	23.67	41.62	2.00
23	RC-101	57.00		1.33	33.33	29.09	3.07
24	GCP-232	51.67		1.50	28.00	27.39	2.70
25	GCP-234	50.67		2.50	26.67	24.93	3.20
26	GCP-297	52.00		2.17	25.00	35.34	2.23
	Gm	50.30		2.94	27.55	28.76	2.50
	cd at 5%	3.19		0.87	6.28	4.00	0.79
	cv	3.87		18.16	13.91	8.48	19.29

Results

The results revealed that the entries CST-5 showed minimum days to 50% flowering (40.67 days), follwed by Pant Lobia-4 (41.00 days) which was used as check. Other entries showing less days to 50 % flowering are CST-15 (46.00 days) and CST-3 (46.33 days). Regarding the maturity, The entries showing earliest maturity are Pant Lobia-4, the check (71.33 days), followed by CST-2 and CST-5 both showing 71.67 days. CST-9 (72.33 days) and CST-11 (72.67 days) also exhibited early maturity. The main trait to be observed i.e. thrip score showed that CST-7 showed least damage by thrip, it was totally free from thrips and thus was considered to be resistant to thripps and thus assigned a score of 1.00. Other entries viz., GCP-232 (1.50), Pant Lobia-3, the check (200), CST-6, CST-14 and CST-297 were moderately resistant to thrips. For plant height, CST-7 showed maximum plant height (34.33 cm), followed by Pant Lobia-3 (32.33 cm), CST-9 and CST-11 both showing similar height (30.33 cm) and CST-14 showed 30.67 cm height. For dry weight, the maximum dry weight was shown by CST-13 (43.45 grams), followed by CST-4 (42.16 grams) and Pant Lobia-5 (41.62 grams).

Discussion

The increased dry weight can be attributed to the effectiveness of the nodulation. A similar result was reported by Salih (2002) [28] who observed increased shoot dry weight in soybean plants inoculated with *Bradyrhizobium* strains.

Regarding the main effect, the highest nodule number was recorded from CST- 11 (3.23), followed by CST-5 and CST-7 (3.20), CST-6 (3.00). For the yield, the highest yield was reported from CST-6 (24.44 qtl/hac), followed by CST-13 (21.57), CST-4 (18.29) and CST-14 (16.20). The marked variation in nodule number per plant among the varieties could be attributed to difference in the genetic makeup of the individual varieties (Ayodele and Oso, 2014), Manish *et al*. (2011). The highest yield was recorded by CST-6 (24.44 qtl/hac) followed by CST-13 (21.57 qtl/hac), CST-4 (18.29 qtl/hac) and CST-14 (16.20 qtl/hac). Thus, the selection of highly nodulation producing varieties and hence the amount of N fixed and yields of the crop will lead to increased production and seed yield of crop. Similar results were obtained by Sharma and Kumawat (2011) [30], who reported increased nodulation by inoculating soybean varieties with Bradyrhizobia strains. Less number of nodule also reported in soybean and chick pea without *Bradyrhizobium* inoculation (Elkoca *et al*., 2008) [31]. For correlation, plant height has the negative correlation with dry weight and nodulation. dry weight has negative correlation with thrips. 50% flowering has positive correlation with maturity. Maturity has negative correlation with thrips score. Negative correlation between grain yield and grain N concentration was reported by others Williams and Nakkoul, 1983; Kyei-Boahen *et al*., 2002) [18, 19].

Conclusion

The results obtained in this study have shown that nodulation is a very important trait of cowpea varieties and it affects the grain yield of cowpea varieties. The higher plant growth and increased nodulation in plants translated into increased grain yield. Based on the findings of the current study the use of cow pea variety CST-6, CST-13 and CST-4 could be recommended for enhanced growth and yield performance of cowpea.

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