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Effect of Phosphorus and Zinc Interactions on Leaf Area Index (LAI) of Cowpea (*Vigna unguiculata* (L.) Walp) Varieties in North Eastern Nigeria

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Abstract

Leaf area index (LAI) is a measure of leafiness per unit ground area. In other words, Leaf area index is defined as the projected area of leaves over a unit of land and denotes the extent of photosynthetic machinery. It is an important growth and yield-determining factor because it is a major determinant of light interception and transpiration. Phosphorus (P) and Zinc (Zn) are the most important factors affecting LAI of cowpea (Vigna unguiculata L. Walp).Two field trials were conducted at the Faculty of Agriculture and Agricultural Engineering Research Farm of Abubakar Tafawa Balewa University, Bauchi, North Eastern, Nigeria, between 2006 and 2007 to assess the effect of phosphorus (0, 25, 50 kg P/ha) and zinc levels (0, 2.5, 5 kg Zn/ha) on LAI of six cowpea varieties namely: IT90K-277, IT93-455-1, IT89KD-288, IT97K-568-18, IT90K-82-2 and Kanannado. The main objective of this experiment was to investigate whether there is any difference in the LAI of cowpea varieties at various P and Zn levels or not? Bauchi is situated at 10⁰ 22′, N latitude and 90⁰ 47′ E longitude at about 109.45m above sea level. The increase in LAI was attributed to the increase in leaf number and leaf area/hill. The differences in LAI observed in the varieties may be attributed to the differences in phenotypes and climatic factors such as rainfall, sunshine and availability of nutrients. The increase in LAI showed a positive impact on crop growth rate, dry matter, and yield. Application of 25 kg P+2.5 kg Zn/ha to cowpea variety IT93-455-1 was more beneficial in terms of higher LAI and productivity in Bauchi.

Keywords: Cowpea varieties, leaf area index, *Vigna unguiculata* L., P levels, Zn levels

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is a major leguminous food crop cultivated all over the world (Musa *et al*., 2017). It is one of the most ancient crops known to man. Its origin and subsequent domestication is associated with pearl millet and sorghum in Africa. It is an integral part of traditional cropping systems throughout the continent, particularly in the semi-arid region of West Africa (Steele, 1972). It is now a broadly adapted and highly variable crop, cultivated around the world primarily for seed, but also as a vegetable (for leafy greens,

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green pods, fresh shelled green peas, and shelled dried peas), a cover crop and fodder (Quinn, 2004).

Phosphorus is a necessary nutrient for the biosynthesis of chlorophyll. Phosphorus as a constituent of cell nucleus is essential for cell division and development of meristematic tissue. Phosphorus deficiencies lead to a reduction in the rate of leaf expansion and photosynthesis per unit leaf area hence reduction in fodder yield. Crop yields are often limited by low soil levels of mineral micronutrients such as zinc (Zn). Essentiality of zinc in plants was established as early as 1915 by Maze in maize. Zinc is an essential mineral nutrient and a cofactor of over 300 enzymes and proteins involved in cell division, nucleic acid metabolism and protein synthesis (Marschner 1986). Cakmak (2000) has speculated that zinc deficiency stress may inhibit the activities of a number of antioxidant enzymes, resulting in extensive oxidative damage to membrane lipids, proteins, chlorophyll and nucleic acids. Zinc can affect carbohydrate metabolism at various levels. Further, Zn is required in the biosynthesis of tryptophan, a precursor of the auxin-indole-3-acetic acid (Oosterhuis *et al.*, 1996). Zinc deficiency symptoms include, small leaves, shortened internodes giving the plant a stunted appearance. Availability of zinc in soils and its absorption and translocation in plants is influenced by all other plant nutrients. Zinc in general interacts negatively with phosphorus which depends upon a number of physicochemical properties of soils (Kumar *et al*., 2016).

Plant growth analysis is generally expressed as indexes of growth such as crop growth rate, relative growth area, net assimilation rate, leaf area ratio, and leaf area index (Fageria *et al*., 2006) that provide the first clue toward an understanding of variation in growth rates among genotypes or species (Lambers, 1987).LAI is a measure of leafiness per unit ground area and denotes the extent of photosynthetic machinery. LAI influences the interception and utilization of solar radiation, and consequently, growth and yield (Amanullah *et al*., 2016). According to Fageria *et al*. (2006), LAI is an important yield-determining factor for field grown crops because LAI is a major determinant of light interception and transpiration. Rapid leaf area expansion is a desirable trait in the early growth stages of cereal crops grown in low-rainfall areas, because it leads to rapid canopy closure, thereby reducing the evaporation from the soil surface, and thus increasing crop water use efficiency (Richards et al., 2002). In more favourable conditions, fast canopy development will make the crop more competitive with weeds for light interception (Lemerle et al., 2001). The main objective of this experiment was to investigate whether there is any difference in the LAI of cowpea varieties at various P and Zn levels or not?

MATERIALS AND METHODS

Description of the Site of the Study

Field trials were conducted at the School of Agriculture Research Farm of the Abubakar Tafa wa Balewa University, Bauchi, Nigeria, during the planting seasons of 2006 and 2007 to inve stigate the effects of phosphorus and zinc interactions on leaf area index (LAI) of cowpea (*Vi gna unguiculata* (L.) Walp) varieties. Bauchi, is situated at 10.3010° N latitude and 9.8237° E longitude at an altitude of 109.45m above sea level. It has a monsoonal climate characterized by well-defined rainy and dry seasons. Annual rainfall is mostly distributed between the months of May and October. Average rainfall for the 2006 and 2007 mean monthly temperature; and other meteorological data collected during the experimental periods are presented in Tables 1 and 2, respectively.

The soils of the experimental site were found to be moderately well drained, deep, and tropically sandy loam. The physico-chemical properties of the soil of the experimental sites for the two years were determined using the procedures described by Black (1965) and are presented in Tables 3, and 4.

Field Experimental Design

For the field experiment, a split-split plot design was used. Total size of the experimental area was 62m by 50 m. There were three (3) replicates and each replicate comprised of three sub-plots; each measuring 18.9 m by 2.25 m. Each sub-plot was divided into six (6) sub-sub-plots with each measuring 6.30m by 2.25m. A space of 1m each was left between main plots, and replicates. Half a meter (0.5m), and 50cm were left between sub-plots, and sub-sub-plots respectively. Main plots were assigned to three different levels of single super phosphate (SSP) namely 0kgha-1, 25kgha-1, and 50kgha-1at random. Sub-plots were assigned to three (3) different levels of Zinc (Zn) namely 0kgha-1, 2.5kgha-1, and 5kgha-1. In all, there were fifty four (54) treatments; that is six varieties by three SSP levels by three Zinc levels. The treatments outlined above were randomized using table of random numbers as described by Gomez and Gomez (1984). The experiment continued up to three and half (3½) months that is, from planting to harvest period.

Experimental Plant Materials

Six cowpea varieties collected from International Institute for Tropical Agriculture (IITA) were used in the experiments. The varieties are IT90K-277, IT93-455-1, IT89KD-288, IT97K-568-18, IT90K-82-2, and Kanannado. Table 5 described the growth characteristics of the cowpea varieties used in the study.

Soil Sampling and Analysis

Soil samples were collected from random selected spots on the experimental field before land preparation each year. The samples were taken at two depths (0-15 and 15-30cm), using a tubular auger. The physiochemical properties of the soil were determined using procedure described by Black (1965). The following soil properties were studied: Nitrogen, phosphorus, potassium, power of hydrogen (pH), cation exchange capacity (CEC) and particle size (Tables 3, and 4).

Land Preparation

The land was cleared, ploughed and harrowed. It was then marked into 162 sub-sub-plots. The sub-plot size was 14.2cm^2. There were 18 sub-sub-plots in a main plot, and 3 main plots in a replicate, and 3 replicates in the whole field experiment.

Sowing of Cowpea Varieties

Sowing was done 3rd and 5th August for the years 2006 and 2007, respectively. Sowing was 75cm row to row and 25cm plant to plant, and three seeds per hill. Seedlings were thinned to one per hill two weeks later. The planting dates were considered in such a way that the varieties mature after end of the rainy season as recommended by IITA (2000).

Fertilizer Application (SSP and Zinc)

Single Super Phosphate (SSP) was incorporated into the soil before sowing as top dressing is not recommended by ITTA (2000). Soil application of phosphorus is more effective in increasing phosphorus content (of the soil) than foliar application (IITA, 1973). Zinc sulphate was used as the sources of Zinc and was incorporated in to soil.

Weeds and Pest Control

The first weeding (hoe weeding) was done about three weeks after sowing (21 DAS). Second weeding was at 42 DAS. For the control of insect pests, three sprays of insecticides at 30, 50 and 60 days were used, using an insecticide called *dimethyl cyclopropanecarboxylate* (karate).

Determination of Leaf Area Index (LAI)
The leaf area index was determined as $LAI = (A X N) X 10{,}000$; where A is leaf area (cm^2) and N is number of branches (Fageria *et al*. 2006).

Data Collection
Data were collected from the net plots leaving the gross plots to serve as borders. Data collected were based on growth and yield parameters. The growth and yield parameters include: Emergence count, Plant height (cm), Number of branches/plant, Number of leaves/plant, Leaf area index, Leaf chlorophyll content, Average number of pods/plant, Average pod weight/plant (g), Number of seed/pod, Hundred seed weight (g) and Grain yield (kg/ha).

Data Analysis
The results obtained were analyzed using analysis of variance (ANOVA). F test was used for a split-split-plot design using SAS software to test for significant effects of treatments as described by Snedecor and Cochran (1967), Gomez and Gomez (1984), where the observed variance ratios were compared with the table values at either 1 or 5%. Differences between means were separated by the use of Duncan multiple range test (DMRT). Correlation and path co-efficient analyses were carried out to ascertain the causes and effects of the parameters on the seed yield using the procedure described by Little and Hills (1978) in order to assess the type and magnitude of the cause and effect relationships among the variables.

Table 1. Meteorological observations for the year 2006

		Temp (^{0}C)		Rel. hum. (%)		
Month	Rainfall (mm)	Min	Max	am	pm	Sunshine (h)
January	0	14.6	30.6	25.65	13.62	8.94
February	0	18.3	36.2	23.66	10.65	9.60
March	26.5	21.6	36.8	86.10	8.11	8.60
April	82.6	24.7	36.7	91.43	12.66	8.40
May	150.2	22.8	32.2	93.10	42.05	5.89
June	106.6	22.5	32.6	90.20	46.80	8.29
July	282.4	20.8	30.4	95.40	58.00	7.99
August	244.6	19.4	28.6	98.20	56.90	6.19
September	135.85	20.5	29.9	80.20	54.70	9.00
October	19.4	19.6	30.8	75.00	24.60	9.19
December	0	13.1	31.4	32.60	14.50	9.00

Source: Bauchi Agricultural Development Project, Bauchi, Nigeria.

Table 2. Meteorological observations for the year 2007

Month	Rainfall (mm)	Temp (^{0}C) Min	Temp (^{0}C) Max	Rel. hum. (%) am	Rel. hum. (%) pm	Sunshine (h)
January	0	12.6	26.7	34.23	17.58	8.63
February	0	16.2	33.4	25.11	13.00	8.70
March	24.10	21.2	35.9	39.10	8.22	8.90
April	47.5	23.6	38.6	67.43	16.80	8.60
May	50.3	24.3	36.8	77.18	23.11	7.63
June	179.2	23.7	33.5	88.23	42.58	9.20
July	320.9	20.8	29.6	96.20	47.26	10.43
August	389.3	20.6	30.8	94.45	47.50	8.93
September	360.4	20.2	32.9	90.80	45.70	10.40
October	29.11	18.6	33.7	74.12	28.11	9.90
November	0	16.7	34.6	36.76	20.10	9.60
December	0	12.8	29.3	33.90	17.50	8.90

Source: Bauchi Agricultural Development Project, Bauchi, Nigeria.

Table 3. Physico-chemical Properties of the soil at the study before the trials at the 0-15 and 15-30 cm soil depth Soil properties in 2006

	0-15 cm	15- 30 cm
Particle size distribution		
% Sand	77.0	78
% Slit	7.5	7.9
%Clay	13.0	12.4
Chemical properties		
pH in water	5.5	6.0
pH in 0.01MKCl	4.4	4.7
Organic Carbon (%)	0.76	0.70
Total nitrogen (%)	0.04	0.04
Available P (ppm)	16.5	16.4
C.E.C (Meq 100^{-1}g Soil)	4.9	4.8

Table 4. Physico-chemical Properties of the soil at the study before the trials at the 0-15 and 15-30 cm soil depth Soil properties in 2007

	0-15 cm	15- 30 cm
Particle size distribution		
% Sand	76.9	78.5
% Slit	8.5	8.3
%Clay	13.6	13.0
Chemical properties		
pH in water	5.9	5.7
pH in 0.01MKCl	4.6	4.8
Organic Carbon (%)	0.72	0.74
Total nitrogen (%)	0.03	0.03
Available P (ppm)	17.8	17.5
C.E.C (Meq 100^{-1}g Soil)	4.46	5.0

Table 5. Description of growth and morphological characteristic of the cowpea varieties used in the study

Variety	Photosensitive	Resistant	Maturity	Morphological status	Yield/ha
IT90K-227	Photosensitive	Resistant to striga, virus, and several diseases	75 – 80 days	A semi-erect type	2371kgh^{-1}
IT93-455-1	Photosensitive	Resistant to pests and diseases	Matures at 65 days	A semi-erect type	1572 kgh^{-1}
IT89KD-288	Photosensitive	Moderately resistant to striga	80-85 days	A semi-erect type	1684 kgh^{-1}
IT97K-568-18	Photosensitive	Resistant to pests and diseases	70-75 days	A semi-erect type	2488kgha^{-1}
IT90K-82-2	Photosensitive	Resistant to aphids, bruchids, etc	56-70 days	A semi-erect type	1785kgha^{-1}
Kanannado	Strongly Photosensitive	Susceptible to several diseases and insect pests	80-114 days	A spreading type	1895kgha^{-1}

Source: International Institute for Tropical Agriculture (IITA) (2000)

RESULTS

Leaf area Index

Year had no significant effect on LAI at 3, 5, and 7 WAS. Significant effect on year on LAI was observed at 9 and 11 WAS, where, 2006 recorded higher effect than 2007. Effect of varieties, SSP, and Zinc levels were found to be significant on LAI throughout sampling periods (Tables 6, 7, and 8). In 2006, IT93-455-1 and IT89KD-288 induced highest and least effects on LAI, respectively (Table 6). Effect of varieties on LAI in 2007 revealed that higher and lower effects were recorded by IT93-455-1 and IT89KD-288, respectively. Varieties were found to induce significant effects on LAI at combined levels (2006 and 2007) throughout sampling periods.IT93-455-1 was found to record higher effects on LAI while IT89KD-288 and IT97K-568-18 recorded the least effect on LAI (Table 6).

SPP levels were observed to have shown significant effect on varieties in 2006, 2007, and combined effects of the two years (Tables 6, 7 and 8). 25SSP kgha^{-1} was found to record higher effect on LAI, in 2006, 2007, and at combined effect of two years. The control (0SSP kgha^{-1}) recorded the least effect on LAI, at the same periods.

In 2006, Zinc levels had significant effect on LAI throughout sampling periods, except at 7 WAS. 5 and 2.5 Zn kgha^{-1} recorded the highest and least effects, respectively, at 11 WAS (Table 6). Effect of Zinc levels on LAI in 2007, was significant at 7, 9, and 11 but not at 3, and 5 WAS 5 Zn Kgha^{-1} induced higher effect at 7, and 9 but not at 11 WAS, where, the control recorded higher statistical value than 5Zn kgha^{-1} (Table 6). The combined effect of two years on LAI indicated that, Zinc levels had significant effect at 7, 9, and 11 but not at 3, and 5 WAS. 5 and 2.5 Zn kgha^{-1} was observed to induce the higher and least effects on LAI (Table 6).

In 2006, interactions (V x P, V x Zn, P x Zn, and V x P x Zn) had significant effects on LAI throughout Sapling periods. Interactions that were no significant on LAI included V x Zn, and V x P x Zn, at 9, and 7 and 9 WAS, respectively (Table 6). In the year 2007 P x Zn and V x P x Zn were found to have significant effect on LAI throughout sampling periods except at 11 WAS.

Interaction between variety and phosphorus (V x P) was found to have significant effect on LAI throughout sampling periods except at 5 WAS. Variety and Zinc (V x Zn) had no significant effect on LAI throughout sampling periods except at 7 WAS (Table 6).

On the combined interactive effects, these interactions were observed to be significant on LAI at the following sampling periods: At 3 WAS: V x Zn, P x Zn, V x P x Zn, Y x P, Y x V x P x Zn and Y x P x Zn. At 5 WAS: V x Zn, P x Zn, P x Zn, and V x P x Zn At 7 WAS: V x Zn, P x Zn, V x P x Zn, Y x V, and Y x V x Zn. At 9 WAS: V x P, V x Zn, P x Zn, V x P x Zn, Y x P, Y x V x P and Y x V x Zn. At 11WAS: V x Zn, P x Zn, V x P x Zn, Y x Zn and Y x V x P.

Table 6. Effects of Single Super Phosphate and Zinc levels on leaf area index (cm) of cowpea varieties grown at Bauchi, Nigeria, 2006

Treatment	Sampling dates (WAS)				
	3	5	7	9	11
Varieties					
IT90K-277-2	0.04d	0.19c	0.62d	0.74d	0.83c
IT93-455-1	0.07b	0.53a	1.20a	1.35a	1.45a
IT89KD-288	0.04d	0.38b	0.56b	0.74d	0.81c
IT97K-568-18	0.06c	0.33b	0.64b	0.74d	0.82c
IT90K-82-2	0.09a	0.51a	0.71a	0.81c	0.89b
Kanannado	0.07b	0.52a	1.08a	1.11b	1.12a
SE ±	0.005	0.034	1.071	0.067	0.061
SSP ($kgha^{-1}$)					
0	0.05c	0.37b	0.69b	0.80b	0.88c
25	0.07a	0.44a	0.83a	0.97a	1.07a
50	0.06b	0.42a	0.83a	0.97a	1.02b
SE ±	0.003	0.02	0.050	0.047	0.043
Zinc ($kgha^{-1}$)					
0	0.04b	0.42a	0.79	0.89a	0.99b
2.5	0.06a	0.38b	0.70	0.79b	0.90c
5.0	0.06a	0.42a	0.91	1.05a	1.09a
SE ±	0.003	0.027	0.050	0.047	0.043
Interaction					
V x P	**	**	**	**	**
V x Zn	**	**	*	n.s	**
P x Zn	**	*	*	**	**
V x P x Zn	**	**	n.s	n.s	**

Means in a column followed by the letter(s) within treatments are not significant different at 5% level of probability using DMRT

Table 7. Effects of Single Super Phosphate and Zinc levels on leaf area index (cm) of cowpea varieties grown at Bauchi, Nigeria, 2007

Treatment	Sampling periods (WAS)				
	3	5	7	9	11
Varieties					
IT90K-277-2	0.04e	0.26d	0.64c	0.76c	0.91c
IT93-455-1	0.07b	0.51a	1.12a	1.17a	1.19a
IT89KD-288	0.05d	0.36c	0.58d	0.76c	0.80e
IT97K-568-18	0.06c	0.42b	0.75a	0.78c	0.97b
IT90K-82-2	0.08a	0.50a	0.71b	0.88b	0.85d
Kanannado	0.07b	0.44b	0.78ba	0.95	0.93c
SE ±	0.004	0.033	0.038	0.041	0.035
SSP ($kgha^{-1}$)					
0	0.05c	0.37c	0.72b	0.82b	0.19
25	0.07a	0.64a	0.79a	0.90a	0.93
50	0.06b	0.41b	0.79b	0.90a	0.89
SE ±	0.003	0.024	0.027	0.029	0.024
Zinc ($kgha^{-1}$)					
0	0.06	0.42	0.72b	0.89b	0.94a
2.5	0.06	0.41	0.68c	0.80c	0.86b
5.0	0.06	0.42	0.89a	0.93a	0.93a
SE ±	0.003	0.024	0.027	0.029	0.024
Interaction					
V x P	**	n.s	**	*	*
V x Zn	n.s	n.s	*	n.s	n.s
P x Zn	**	**	**	**	n.s
V x P x Zn	*	*	*	**	n.s

Means in a column followed by the letter(s) within treatments are not significant different at 5% level of probability using DMRT

Table 8. Combined effects of Single Super Phosphate and Zinc levels on leaf area index (cm) of cowpea varieties grown at Bauchi, Nigeria, 2006 and 2007

Treatment	Sampling periods (WAS)				
	3	5	7	9	11
Year (Y)					
2006	0.06	0.41	0.80	0.91a	0.99a
2007	0.06	0.41	0.76	0.87b	0.91b
SE ±	0.001	0.008	0.008	0.018	0.000
Varieties					
IT90K-277-2	0.04c	0.22d	0.63d	0.75c	0.87c
IT93-455-1	0.07a	0.52a	1.16a	1.23a	1.32a
IT89KD-288	0.05b	0.37c	0.57e	0.75c	0.81d
IT97K-568-18	0.06b	0.38c	0.70c	0.76c	0.81d
IT90K-82-2	0.08a	0.48b	0.93b	1.03b	1.02b
Kanannado	0.07a	0.48b	0.93b	1.03b	1.02b
SE ±	0.002	0.022	0.022	0.040	0.031
SSP (kgha^{-1})					
0	0.05c	0.37c	0.70c	0.81b	0.89c
25	0.07a	0.45a	0.81b	0.93a	1.00a
50	0.06b	0.41b	0.84a	0.94a	0.96b
SE ±	0.001	0.012	0.012	0.019	0.018
Zinc (kgha^{-1})					
0	0.06a	0.04	0.75b	0.89b	0.97b
2.5	0.06a	0.04	0.69c	0.80c	0.88c
5.0	0.06b	0.04	0.90a	0.99a	0.00a
SE ±	0.001	0.013	0.013	0.021	0.016
Interaction					
V x P	n.s	n.s	n.s	**	n.s
V x Zn	**	**	**	**	**
P x Zn	**	*	**	**	**
V x P x Zn	**	**	**	**	**
Y x V	n.s	n.s	*	n.s	n.s
Y x P	*	n.s	n.s	**	n.s
Y x Zn	n.s	n.s	n.s	n.s	*
Y x V x P	n.s	n.s	n.s	*	**
Y x V Zn	n.s	n.s	**	**	n.s
Y x V x P x Zn	*	n.s	n.s	n.s	n.s
Y x P x Zn	*	n.s	n.s	n.s	n.s

Means in a column followed by the letter(s) within treatments are not significant different at 5% level of probability using DMRT

DISCUSSION

Effects of Year, Phosphorus, Zinc and Interactions on LAI of different Varieties of Cowpea

The finding that year had no significant effect on LAI at most sampling periods corroborated that of Malagi (2006), who observed that year did not affect the LAI of the Cowpea varieties he studied. Leaf area index was observed to be an inventory of the population leaves that are absorbing light and momentum and exchange heat, moisture, CO_2 and trees gases with atmosphere (Albertson *et al.*, 2001). A correlative and biogeographical analysis suggests that LAI is strongly tied to side water balance and nutrient status (Woodward, 1987; Scheffer *et al.*, 2005). LAI is not determined by year or climate variation only, but by a collection of a number of factors including nutrient status as reported by Scheffer *et al.* (2005).

Varieties, Phosphorus, and Zinc levels were found to be significant on LAI. This finding was in congruence with a recent one by Shittu and Ogunwale (2013). In their work on phosphorus zinc interaction for soybean production, Shittu and Ogunwale reported that varieties, SSP and

Zinc levels had significant on LAI and LA of soybean another leguminous crop. According Zhimini *et al*. (1999), addition of P increased the translocation of P and Zn to the leaves. LAI correlates with the photosynthesis, respiration, and transpiration of the plant canopy and thus exchange of energy between ecosystem and atmosphere (Breda, 2003).

Leaf area index of cowpea varieties was observed to be significantly influenced by single super phosphate and zinc applications. Higher leaf area index was observed to be induced by 50kgha^{-1} SSP and 5kgha^{-1} Zn. However, SSP levels were found not have significant effects on leaf area index. Zinc levels were found to have significant effects on leaf area index. Variety x phosphorus was found not to significantly affect leaf area index. Variety x zinc was significant on leaf area index.

CONCLUSION

The results indicated that varieties, P, and Zn levels were found to be significant on LAI throughout sampling periods. In 2006, IT93-455-1 and IT89KD-288 induced highest and least effects on LAI, respectively, whereas in 2007 data collected indicated that highest and least LAI were recorded by IT93-455-1 and IT89KD-288, respectively. When combined over the 2 years, the data revealed that the highest and least LAI were obtained by IT93-455-1 and IT89KD-288 and IT97K-568-18.The highest and least LAI in 2006, 2007, and combined effects of the two years were obtained by application 25 and 0 P kgha^{-1}, respectively. Similarly, the highest LAI was obtained with application of the two higher Zn levels 2.5 and 5 kg Zn/ha, while the lowest LAI was recorded when Zn was not applied (control). IT93-455-1.In the case of cowpea varieties, the highest LAI was obtained from IT93-455-1 than other five varieties at all growth stages. The other five varieties produced statistically similar LAI at different growth stages. The higher LAI of IT93-455-1 was attributed to its long and wider leaves that resulted in higher mean single leaf area, leaf area per hill, and per square meter

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