

Effect of Planting Methods on Growth of Onion (*Allium cepa* var. *Cepa*)

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Abstract: The experiment was conducted at Melkassa center of the Ethiopian Institute of agricultural Research for two season to investigate the effect of different onion planting methods on growth parameters and canopy development of onion cultivars. The experiment consisted of three planting methods of onion, namely direct seeding to the field, transplanting of seedlings and planting sets, and three onion cultivars (Adama Red, Bombay Red and Nasik Red). The experimental design was split plot with three replications; cultivars were assigned to the main plot and planting methods to sub-plot. Data were collected at 55, 70, 85 and 100 days after planting. Leaf area index were significantly ($P < 0.05\%$) higher on sets and transplants at all dates of observation. The correlation analysis results show highly significant ($P < 0.001$) association between plant height, leaf area, LAI and shoot fresh and dry weight, with correlation coefficient ranging between 0.89 and 0.99. This indicates that any one of these parameters can be used for yield estimator depending on the condition and the facilities available. Regression analysis of total yield on leaf area index showed stronger dependence at 85 days after planting than the other dates as observed by a higher value of coefficient of determination ($R^2 = 0.80$). This study indicated that planting method has significant effect on the growth and performance of onion cultivars.

Keywords: Direct Seeding, Onion, Planting Method, Sets, Transplants

1. Introduction

Onion (*Allium cepa* L.) is one of the important horticultural crop in Ethiopia grown throughout the year both for local consumption and export. Its importance is increasing because of its value as a food with a long shelf life being a relatively non-perishable product. However, the productivity of onion in Ethiopia is lower than the world and Africa average. According to FAO [1] report the average yield tones ha⁻¹ for the world, Europe, Asia, American, Africa and Ethiopia are 19.31, 25.42, 18.36, 31.58, 14.64 and 10.48, respectively. According to CSA [2] the total land area under onion production is 22771.88 hectares and 705877 households owning the land under onion production with total production of 0.25 million tons of dry bulbs and productivity of 10.1 tones ha⁻¹.

Onion dry bulb are commonly established in the field

either by direct sowing of seeds to the field, or by transplanting seedlings from seedbed or from sets depending on the growing conditions of the specific locations. Sowing seeds directly into the field where the crop is to be grown is considered an economical method of producing particularly where there is limited availability of labor for transplanting, high labor cost, or limited availability of facilities for raising transplants [3]. Sets and transplants are practiced in areas where the season is not long enough for proper bulb development.

Leaf area is an important physiological component of crop yield, being itself a complex character. Genotypic differences in yield of many crops are mainly associated with variations in leaf area [4]. Interception of PAR by a crop canopy is strongly related to total leaf area. A crop will thus intercept more PAR and hence grow faster if it develops leaf area rapidly [5]. Crop yield is affected by genotype and may be attributed to variations in the amount of leaf area. The

proportion of the total incident light intercepted by leaves depends on Leaf Area Index (LAI). Large LAI promotes efficient utilization of the incident photosynthetic active radiation (PAR) and increase dry matter yield [3]. In onion high bulb yield was reported from cultivar that had large LAI and intercept high percentage of light by the leaf canopy [3]. Report in clover [6] indicated net photosynthetic rate of canopies increased linearly with leaf area index (LAI) up to an LAI of 3.5 and then declined at higher LAI, independent of variety and sowing density. According to this report below the optimum LAI, net photosynthesis depended mainly on interception of PAR. Decrease in canopy photosynthesis above the optimum LAI was due to a higher proportion of old leaves with decreased photosynthetic capacity. Therefore, an experiment was carried out to investigate the effect of different onion planting methods on growth parameters and canopy development of onion cultivars.

2. Material and Methods

The experiment was conducted for two seasons on rainy season and under irrigation at Melkassa Research Center of the Ethiopian Institute of Agricultural Research (EIAR). The experiment consisted of three factors; planting methods (direct seeding, transplanting and sets), onion cultivars (Adama red, Bombay red and Nasik red) and different growth periods (55, 75, 85 and 100 days after planting) in factorial split-split-plot design with three replications. The cultivars were assigned in the main plots, planting methods to the sub-plots and growth stages as sub-sub plots. The plot size was 9 m² (3 m x 3 m) with 10 single rows per plot and 30 plants per row with a total of 300 plants per plot. Spacing between water furrows, plant rows and plants was 40 cm, 20 cm and 10 cm, respectively. Plots and blocks were separated by 1 m and 1.5 m alleys, respectively.

For treatment involving sets, seeds were seeded on seedbed 30 days earlier than seeds sown for transplanting. Sets and seedlings were ready for transplanting 74 and 44 days after sowing, respectively. Sets with 2-3 cm in diameter were selected for planting. Sets, seedlings and seed were planted in the field on the same date. Plants from direct sowing were thinned 40 days after sowing to maintain the spacing between plants at 10 cm. For set and transplanting treatments, Diammonium phosphate (DAP) was side-dressed at a rate of 200 kg/ha at field planting, and Urea was side dressed at 50 kg/ha twice, at the time of field planting and 45 days after transplanting. Similarly, for direct sowing DAP at 200 kg/ha was applied at seeding, and Urea at 50 kg/ha was applied 40 days after seeding, at thinning, and one month later. All plots were irrigated twice a week from field planting until full bulb development, and weekly thereafter until 15 days before harvest. Every standard cultural practice such as weeding, hoeing, disease and pest monitoring and management were followed regularly. Ridomil G. MZ, 68% at a rate of 3.25 kg/ha in 700 liters and Selecron 72% at a rate of 3 liters per ha in 600 liters of water were applied to control purple blotch and thrips, respectively.

Data on plant height, number of leaves per plant, shoot and bulb dry weight, leaf area and leaf area index was based on five plants, and was taken at 55, 70, 85 and 100 days after planting (DAP) by destructive method from second and third rows in both directions next to guard rows. Data were randomly taken from five plants from each plot. Shoot and bulb weight was measured using sensitive balance with a precision of 0.1 g. Leaf area was measured by taking the leaves from each plot, using portable leaf area meter (model CI-202, NABASEKE, USA), and divide by the number of plants taken and leaf area index (LAI) was calculated by dividing the total leaf area of a sampled plant by the ground area.

Data were checked for normality and constant variance assumptions and square-root transformation carried out for leaf number, LAI, shoot fresh and dry weight, and bulb fresh and dry weight to stabilize the error variance before subjecting the data to ANOVA. The analysis was performed using the SAS statistical package [7]. When significant differences were observed in the ANOVA, mean separation was performed using Student-Newman-Keuls (SNK) test. Correlation and regression analyses were carried out to establish relationship between different parameters.

3. Result and Discussion

The data from two seasons was pooled in the analysis of variance for planting methods. Interaction effect between cultivars and planting methods was significant for most of the parameter measured. Differences among cultivars and planting methods were significant only for shoot dry weight. Maturity, yield and yield components were reported elsewhere [8].

Plant height: Interaction effect of growth stage, planting methods and cultivars were significant ($P < 0.01$) on plant height. Direct seeding showed constantly lower plant height for all cultivars at all growth stage than transplants and sets. Cultivars Adama red at 55 DAP showed almost similar result both in transplants and sets, at 70 and 100 DAP transplants gave higher values of plant height and at 85 DAP sets had higher value. Bombay red showed almost similar result both in transplants and sets. For cultivar Nasik Red, at 55 and 100 DAP transplants gave higher plant height but at 85 DAP sets gave higher value and at 70 DAP almost similar for both transplants and sets (Table 1).

Leaf number: Interaction effect of planting methods and cultivar was insignificant ($P > 0.05$) on leaf number of onion plant. Planting methods had highly significant ($P < 0.001$) effect on leaf number of onion at all growth period. Number of leaves in transplants and sets were statistically similar at 55, 70 and 100 DAP and set planting showed significantly higher leaf number at 85 DAP than transplants. Direct seeding showed significantly lower values in all growth period than set and transplants (Table 1). For set planted and transplanted onion number of leaf increased constantly and reached a maximum at 85 DAP and start to decrease at 100 DAP. This indicated its maturity, when the crop matures the

number of leaves decrease [9]. Cultivars effect were significant ($P < 0.05$) only at 70 DAP. Cultivar Bombay Red gave statistically higher number of leaf per plant than Adama Red and Nasik Red and Adama Red and Nasik Red gave similar value of leaf number.

Shoot dry weight: Planting methods and cultivar interaction effect on shoot dry weight were none significant ($P > 0.05$) at all growth period. The effect of planting methods on shoot dry weight was highly significant ($P < 0.001$). Shoot dry weight was constantly and significantly ($P < 0.05$) lower for direct seeding than the other methods at all the four dates of measurement. Transplanting method gave significantly higher shoot dry weight (2.11 g) than sets at 55 DAP; the difference was insignificance at other dates (Table 2). Transplants and sets were comparable in most periods of observations. Lower values of shoot dry weight for direct seeding method at the four different dates of growth showed late growth performance of onion planted using this method. On the other hand, higher values of shoot weight recorded

from transplanted and set planted onion than direct sown onion shows faster establishment and a subsequent better growth of the crop planted, and earliness using these methods as observed for leaf area index [10]. Mean shoot dry weight per plant of sets was lowest at 55 DAP, increased during subsequent growth stage, reaching a maximum at 85 DAP and then start to decline. The decrease in shoot dry weight might be due to that the plant can compensate for inadequate photosynthesis during bulb development. Similar to the plant height, no significant difference was observed for dry shoot weight between cultivars

Shoot dry weight correlated positively and highly significantly with plant height ($r = 0.85$, $P < 0.0001$), leaf area ($r = 0.79$, $P < 0.0001$) and LAI ($r = 0.79$, $P < 0.0001$). Transplants and sets scored significantly high plant height, leaf number and LAI (Table 1). The high shoot dry weight of onion plants from transplants and sets is thus due to their effects on the above parameters.

Table 1. Effect of planting method and cultivars on plant height, number of leaf per plant and leaf area index of onion at Melkassa.

Treatments	Plant Height (cm)				Number of leaf per plant				Leaf area index (LAI)			
	55DAP	70DAP	85DAP	100DAP	55DAP	70DAP	85DAP	100DAP	55DAP	70DAP	85DAP	100DAP
Cultivars												
Adama Red	45	50	56	56	6	6 ^b	9	9	0.37	0.64	0.94	0.85
Bombay R.	41	47	52	52	7	8 ^a	10	9	0.40	0.66	0.87	0.71
Nasik Red	40	46	51	55	6	6 ^b	10	10	0.29	0.54	0.99	0.89
P-Val	Ns	Ns	Ns	Ns	Ns	0.03	Ns	Ns	Ns	Ns	Ns	Ns
CV _a	10.9%	11.94%	7.95%	8.5%	16.04%	13.92%	16.74%	14.32%	21.60%	21.43%	28.94%	10.12%
Planting Method												
Direct s.	25 ^c	51 ^b	37 ^b	45 ^b	3.9 ^b	4.3 ^b	6 ^c	7 ^b	0.05 ^b	0.16 ^b	0.30 ^c	0.49 ^b
Transplants	54 ^a	56 ^a	61 ^a	61 ^a	7.6 ^a	7.7 ^a	10 ^b	10 ^a	0.50 ^a	0.89 ^a	1.07 ^b	0.96 ^a
Sets	48 ^b	56 ^a	62 ^a	58 ^a	8.1 ^a	8.1 ^a	12 ^a	10 ^a	0.51 ^a	0.84 ^a	1.42 ^a	0.99 ^a
P-Val	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
C * P												
P-Val	0.01	Ns	0.007	Ns	Ns	Ns	Ns	Ns	0.02	Ns	Ns	Ns
CV _b	9.11%	6.80%	3.89%	7.90%	11.81%	12.18%	10.92%	12.81%	25.46%	22.59%	17.70%	20.65%

Means with the same letter are not significantly different from each other at 5% level of significance

Bulb dry weight: Interaction effect of planting method and cultivars was significant ($P < 0.01$) on bulb dry weight only at 55 DAP. Adama Red and Nasik Red gave highest bulb dry weight when established from sets; Bombay red gave highest when established from transplants than other methods (Figure 1).

Planting methods had highly significant ($P < 0.001$) effect on bulb dry weight at all growth period. Mean bulb dry weight of onion from sets and transplanting gave significantly higher bulb dry weight than direct seeding at all growth period. Transplanting and set planting methods showed statistically similar bulb dry weight at all growth period.

Mean bulb dry weight of transplanting and set planting were 1.18 and 1.3, 2.56 and 2.61, 5.23 and 5.94 and 10.13 and 10.16 gram higher than that of direct seeding at 55, 70, 85 and 100 DAP, respectively.

Effect of cultivar on bulb dry weight was significant ($P < 0.05$) at 55 and 70 DAP. Cultivar Bombay red gave significantly higher bulb dry weight (1.06 and 2.21 g/plant) than Adama red (0.71 and 1.27 g/plant) and Nasik Red (0.68 and 1.34 g/plant). Bulb dry weight increased progressively with crop age regardless of the planting method as can be expected. Bulb dry weight was low at 55 DAP, increasing constantly and reaching maximum at 100 DAP.

Table 2. Effect of planting method and cultivars on Shoot dry weight and bulb dry weight of onion at central rift valley of Ethiopia.

Treatments	Shoot dry weight (g/plant)				Bulb dry weight (g/plant)			
	55DAP	70DAP	85DAP	100DAP	55DAP	70DAP	85DAP	100DAP
Cultivars								
Adama Red	1.28	2.36	4.52	5.53	0.71 ^b	1.27 ^b	3.22	8.22
Bombay R.	1.17	2.64	4.18	4.09	1.06 ^a	2.21 ^a	4.92	9.28
Nasik Red	1.07	2.89	5.04	5.29	0.68 ^b	1.34 ^b	3.87	7.92
P-Val	Ns	Ns	Ns	Ns	0.02	0.01	Ns	Ns
CV _a	36.80%	25.50%	25.34%	19.08%	23.42%	23.66%	43.07%	13.35%

Treatments	Shoot dry weight (g/plant)				Bulb dry weight (g/plant)			
	55DAP	70DAP	85DAP	100DAP	55DAP	70DAP	85DAP	100DAP
Planting Method								
Direct s.	0.19 ^c	0.40 ^b	1.11 ^b	2.33 ^b	0.0003 ^b	0.08 ^b	0.28 ^b	1.71 ^b
Transplants	2.11 ^a	3.42 ^a	5.58 ^a	5.98 ^a	1.18 ^a	2.64 ^a	5.51 ^a	11.84 ^a
Sets	1.21 ^b	3.47 ^a	6.86 ^a	6.60 ^a	1.27 ^a	2.69 ^a	6.22 ^a	11.87 ^a
P-Val	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
C * P								
P-Val	Ns	Ns	Ns	Ns	0.001	Ns	Ns	Ns
CV _b	41.50%	36.29%	35%	24.13%	27.13%	43.91%	40.88%	16.47%

Means with the same letter are not significantly different from each other at 5% level of significance

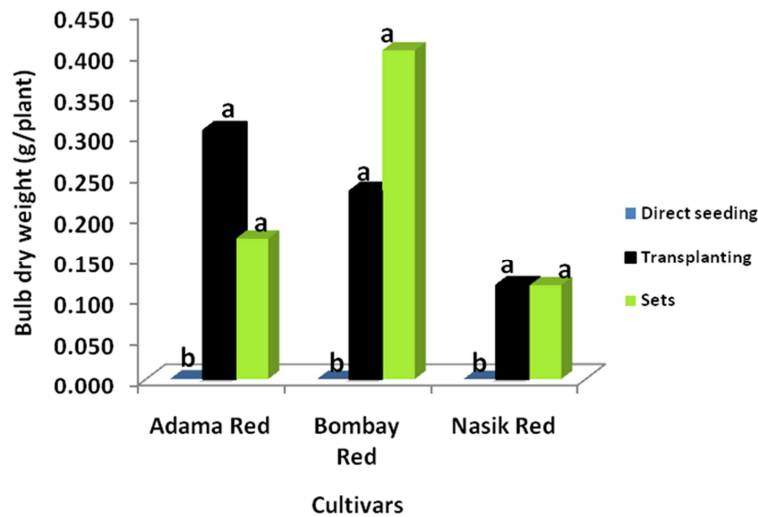


Figure 1. Interaction effect of planting methods and cultivars on bulb dry weight of onion at 55 days after planting.

Leaf area index: Planting method by cultivar interaction was significant ($P < 0.05$) only at 55 DAP. Cultivars Adama Red and Bombay Red gave higher values of LAI using sets than transplanting methods but Nasik Red gave higher LAI from transplants than sets (Figure 2).

Planting method had highly significant effect ($P < 0.001$) on LAI at all growth period (Table 1). Like leaf number mean LAI value of transplanting and sets were statistically similar at 55, 70 and 100 DAP and set planting showed significantly higher LAI at 85 DAP than transplanting method. Direct seeding showed significantly lower values in all growth

period than set and transplants. Mean LAI of sets and transplants were 0.46 and 0.45, 0.68 and 0.73, 1.12 and 0.77, 0.50 and 0.47 higher than that of direct sown onion at 55, 70, 85 and 100 DAP, respectively. The observed higher values of LAI in transplanted and set planted onion than direct seeding in this study could be that both methods allowed better establishment and growth over the direct sown onion. This is in agreement with [10] who reported that transplanting is considered as a planting method that allows a better establishment of onion seedlings over direct sowing.

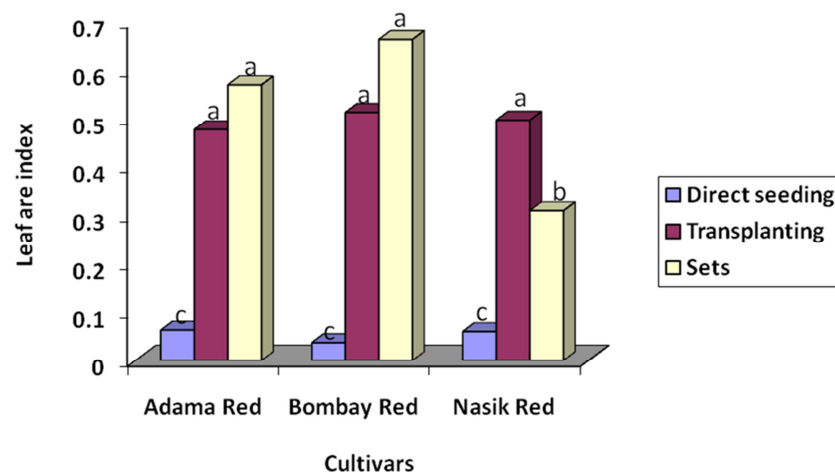


Figure 2. Interaction effect of planting methods and cultivars on leaf area index of onion at 55 days after planting.

High LAI increase light absorption percentage by leaf canopy, which increase bulb yield and early maturity. Previous work [11] reported that factors which contribute to a higher LAI accelerate bulb scale initiation and bulb maturity as bulb yield is correlated with total radiation interception. Mean LAI of sets was low at 55 DAP, increasing constantly at 70 and 85 DAP reaching a maximum at 85 DAP and decrease at 100 DAP. The decrease in LAI might be due to that the plant can compensate for inadequate photosynthesis during bulb development. Cultivars had no significant effect ($P>0.05$) on LAI. This is expectable as varieties did not affect plant height significantly ($P>0.05$) indicating that the contribution of planting methods to yield is higher than the cultivars.

LAI correlated positively and highly significantly with plant height ($r=0.89$, $P<0.001$), leaf area ($r=0.99$, $P<0.001$). Transplanting and set planting methods scored significantly high plant height (Table 1). The high LAI of onion plants from transplanting and set planting methods is thus due to their effects on the above parameters.

Total yield also positively and highly correlated with plant height ($r=0.91$, $P<0.001$), LAI ($r=0.89$, $P<0.001$), Shoot dry weight ($r=0.78$, $P<0.001$). The correlation between these parameters and yield could be due to increased

photosynthesis. Factors which contribute to a higher LAI accelerate bulb scale initiation and bulb maturity as bulb yield is correlated with total radiation interception [11]. Comparing photosynthesis of two soybean varieties with respective yields, a nearly perfect correlation ($r = 0.98$) reported [12]. Similarly, significant linear relationships between leaf area index, intercepted photosynthetic active radiation and dry matter yield in fodder sorghum showed a clear interdependence of growth parameters [13]. Other research work in winter wheat also suggested that a strong correlation ($r= 0.95$) between LAI and leaf dry weight [14]. Higher values of LAI in transplanted and set onions and increased yield level compared to direct seeding onion observed in this study could be due to better establishment and faster growth. The regression analysis also showed the strong relationship between LAI and total yield at 85 DAP than the other dates as observed by a higher value of coefficient of determination ($R^2 = 0.80$) (Figure 3). The correlation analysis results show highly significant ($P<0.001$) association between plant height, LAI and shoot fresh and dry weight, with correlation coefficient ranging between 0.89 and 0.99. This indicates that any one of these parameters can be used for yield estimation depending on the condition and the facilities available

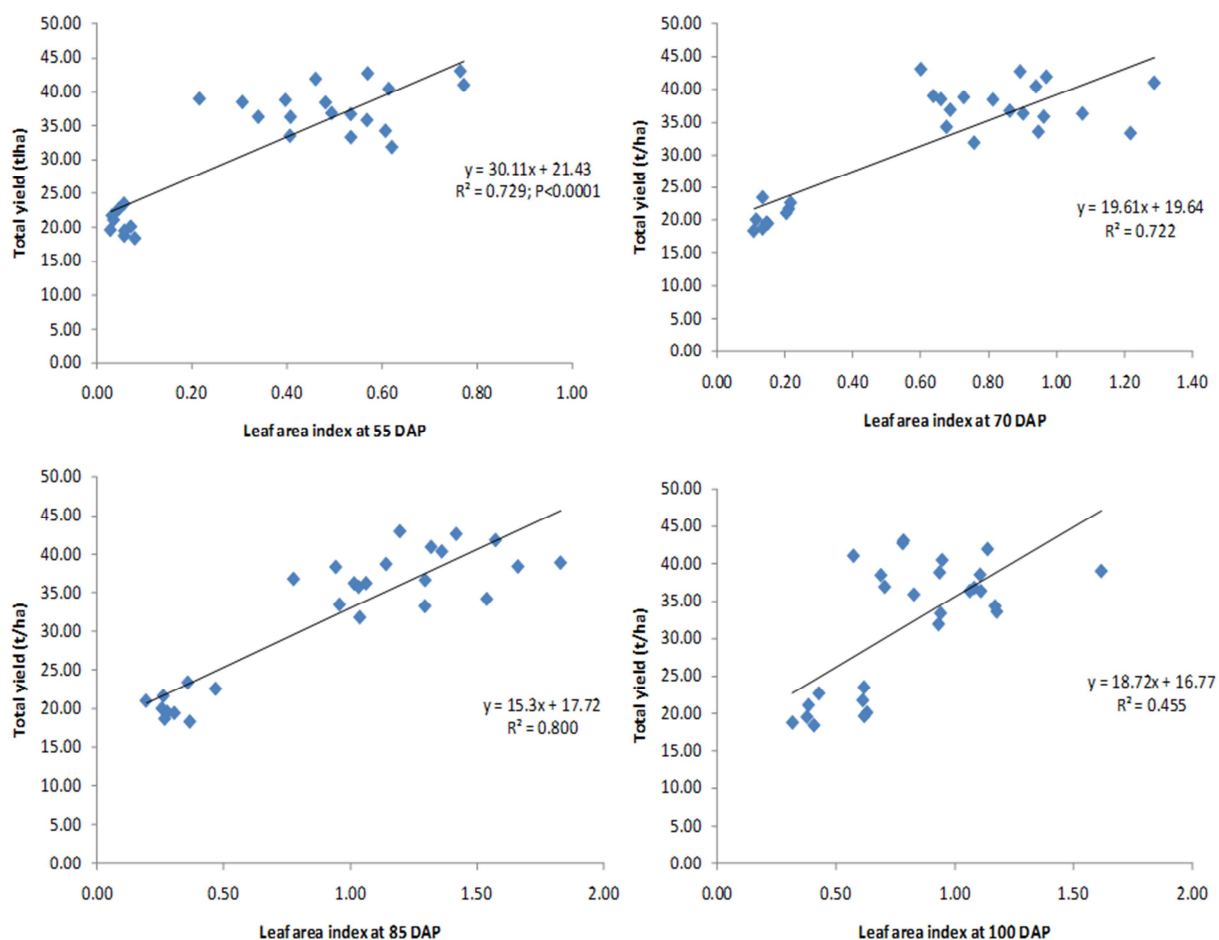


Figure 3. Regression lines showing the relationship between leaf area index with total yield at different dates of onion growth; DAP – Days after planting.

Table 3. Pearson Correlation coefficient among growth parameter (at 85 DAP), dry bulb yield and bulb quality of three onion planted at different planting methods.

Parameters	PH	LN	LA	LAI	SFW	BFW	SDW	BDW	TY
PH	1								
LN	0.80***	1							
LA	0.89***	0.94***	1						
LAI	0.89***	0.93***	0.99***	1					
SFW	0.91***	0.86***	0.95***	0.95***	1				
BFW	0.86***	0.87***	0.86***	0.86***	0.81***	1			
SDW	0.85***	0.84***	0.79***	0.79***	0.75***	0.94***	1		
BDW	0.80***	0.83***	0.79***	0.79***	0.75***	0.94***	0.83***	1	
TY	0.91***	0.90***	0.89***	0.89***	0.84***	0.88***	0.78***	0.82***	1

PH=plant height, LN=leaf number, LA=leaf area, LAI=leaf area index, SFW=shoot fresh weight, BFW=bulb fresh weight, SDW=shoot dry weight, BDW=bulb dry weight, TY=total yield, Ns= non significant. *, **, and *** denoted significant at 5%, 1% and 0.1%, level respectively.

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