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Influence of growing direction on seed yield and quality in bottle gourd (*Lagenaria siceraria*)

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ABSTRACT

The present investigation was carried out to study the influence of growing direction, i.e. E-W and N-S direction on growth, flowering, fruit set, seed yield and quality attributes of bottle gourd (*Lagenaria siceraria* (Mol.) Stand) at SPU, IARI, New Delhi during *kharif* 2014. The results revealed that growth characters i.e. vine length, leaves/vine, leaf area, leaf nodes/vine, primary laterals and leaves on primary laterals had significantly higher in E-W direction at 45 DAS and leaves/vine, leaf area, leaf nodes/vine, leaves on primary laterals and secondary laterals at 55 DAS. The reduction in number of days to anthesis of first male flower and female flower in E-W direction as compared to N-S direction was observed. Significantly more number of male flowers and less female flower per plant were recorded in E-W direction along with less sex ratio. The fruit development attributes, i.e. fruit set/vine, fruit developed to maturity, fruit weight, fruit length, fruit width, cavity volume and thickness of fruit wall were reported significantly higher in E-W direction. Seed yield attributes, i.e. seed yield/fruit, seed yield/vine and seed yield/acre were found significantly higher in E-W direction but number of total seed, filled seed and unfilled seed per fruit showed at par among the direction of sowing. Similarly seed quality attributes, viz. seedling length (43.49cm), seedling dry weight (0.687 g), vigour index I (4247.37) and VI-II (67.13), seed coat weight and embryo weight were recorded significantly superior in E-W direction than N-S direction. Germination (%) and electrical conductivity of seed leachate showed at par performance among the both the direction of sowing.

Key words: E-W direction**,** Laterals, N-S direction, Seed quality, Seed yield and Vigour index

The seed production of cucurbits especially bottle gourd (*Lagenaria siceraria* (Mol.) Stand) is largely done through the traditional system of growing in which the vines are allowed to spread on the ground. Hence, the production of flowers, fruit setting and development, seed yield and quality etc. are greatly affected. Thus, the available production technology of these crops does not provide a platform for optimum growth and yield. Under field conditions, seed yield and above ground biomass is proportionally related with intercepted photosynthetically active radiation (IPAR) which depends on leaf area index and crop architecture (Plenet *et al*. 2000). Main challenges to the agricultural scientists is to increase the production by harvesting the natural resources like solar radiation (light) and precipitation to the maximum extent and suppress the pest and disease incidence using alternate methods and technology with minimum application of harmful chemicals to save the environment. In the present study we hope to enhance the seed production of bottle gourd through better light interception and suppress the pest and disease incidence by altering the micro-climate within the crop canopy. Direction of sowing can influence the light interception as well as crop canopy micro-climate significantly which in turn may change the crop growth parameters and pest and disease scenario. Similarly, a uniform distribution and proper orientation of plants are needed for greater light interception throughout the crop canopy and maximize photosynthetic efficiency of all the leaves of a plant (Evers *et al.* 2009). Jha *et al.* (2012) studied the effect of direction of sowing and crop phenotype on light interception efficiency and yield of mustard. Zhang *et al.* (2008) reported that in field crops, there is often a linear relationship between cumulative intercepted photosyntheticaly active radiation (PAR) and accumulated biomass. Borger *et al.* (2010) under took studies in wheat and barley and found that wheat yield was 24% more and barley yield 26% more in E-W oriented crop to N-S oriented crop. Bisheshwor *et al.* (2013) observed that wheat varieties (Gautam and BL-2800) yielded about 11% higher grain in the north-south sowing as compared to the east-west sowing. In bottle gourd seed production, there are different opinions about the best direction of sowing for high seed yield and quality. No consensus reached yet with definite scientific explanation and these contradictory findings

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create confusion and needs to be sort out in bottle gourd per-se. Thus, keeping in view of the facts explained about, it is a need of hour to develop and demonstrate a viable seed production technology for bottle gourd for *kharif* season under Delhi weather conditions.

MATERIALS AND METHODS

The bottle gourd cv. Pusa Naveen was used as an experimental material for this study. The field experiment comprises of two direction of growing, viz. East-West (E-W) direction and North-South (N-S) direction (over trailing) with bottle gourd cv. Pusa Naveen was raised at Seed Production Unit Farm (SPUF) during *kharif* 2014. The furrows were opened by middle buster at the spacing of 2.5 m in both the direction in well prepared field. The channels were finally prepared by removing the excess soil and pressed both the sides manually. The seeds were soaked overnight in bavistin (methyl benzimidazol-2-ylcarbamate) solution @ 2 g/kg of seeds and shade dried for two hr. The treated seeds were dibbled @ two seeds per hill by hand at the spacing of 0.50 m in both the direction. The plants were thinned out 20 days after sowing by keeping single healthy seedling per hill. In both the direction of sowing, eight feet length bamboo poles (1.5 inch diameter) were fixed in the soil at 12 feet distance and two poles were connected with 12 feet long bamboo with pole and supported with other bamboos in one side to form right triangle. On the poles, at a height of one meter onwards five to seven rows of flat white plastic rope were tied. The vines were loosely tied with jute thread and trailed over a criss-cross network of plastic ropes.

Thirty plants were randomly selected in E-W and N-S direction plots for recording the biometric observations, viz. vine length (m), number of leaf nodes, leaf area (cm^2), number of primary and secondary laterals, number of leaves on primary and secondary laterals, days to first male and female flowering, number of fruit set and number of fruit develop to maturity. Forty fruits from tagged vine were harvested after ripening for recording post-harvest observations on fruit length (cm), fruit width (cm), fruit weight (kg), fruit cavity (cm), cavity volume (cm^3), and thickness of fruit wall (cm). Seeds were extracted from these forty fruit by manually for recording seed yield and quality observations on 100 seed weight (g), number of filled seeds per fruit, number of unfilled seeds/fruit, number of total seeds/fruit, seed yield/fruit (g), seed yield/vine (g), seed yield/acre (kg), germination (%), seedling length (cm), seedling dry weight (mg), vigour index-I, vigour index-II, electric conductivity (µmhos/cm/g), seed coat weight (mg) and embryo weight (mg). These post-harvest observations were recorded at seed testing lab of Division of Seed Science and Technology, ICAR-IARI, New Delhi. The observations on the environmental parameters such as temperature and light intensity were recorded during flowering and fruit setting period (starting with days to anthesis of first male flower to next 30th day). Temperature within crop canopy were recorded at different heights, i.e. ground, bottom, middle and top of canopy (10 cm below the top most point) with the help of infra-red thermometer (Model no. 6210L) developed by Everest Interscience Inc. Around 2:00 S. (i.e. time of occurrence of daily maximum temperature). Light intensity was measured at 50% height of the crop canopy using Lux Meter (Model: LX-101A LUX METER) developed by HTC™ Instruments at both the side of trailing (exposure & shadow side) in both the direction at three different times i.e. at 8:00 S., 12:00 noon and 4:00 S. Such observations were recorded randomly at six different points in each plot of each direction. The quantitative data generated were analyzed statistically for testing the heterogeneity of means adopting the t-test at 5% probability (P=0.05).

RESULTS AND DISCUSSION

Canopy temperature and light intensity

The observation on temperature behavior and light intensity in E-W direction and N-S direction of sowing

Table 1 Comparison of canopy temperature (°C) in direction of planting in bottle gourd cv. Pusa Naveen

Period*	E-W direction			N-S direction		
	Bottom	Middle	Top	Bottom	Middle	Top
1	31.8	30.7	30.6	39.3	35.7	33.9
2	33.6	31.0	30.2	40.5	37.8	34.2
3	32.2	31.6	31.1	39.5	36.8	32.2
4	33.2	31.9	30.3	38.9	36.2	33.6
5	31.9	30.8	29.4	36.6	36.1	34.4
6	32.7	31.2	29.9	37.4	34.8	32.6
7	34.9	31.9	30.1	39.3	36.3	33.9
8	35.7	32.8	31.7	38.7	35.2	34.1
9	33.7	31.8	30.3	38.2	36.2	34.8
10	34.4	32.6	31.4	36.5	34.7	32.9
11	30.5	29.6	29.3	35.8	33.8	32.5
12	32.6	31.2	30.5	36.5	33.8	33.3
13	32.4	30.3	29.1	35.9	34.5	33.3
14	32.7	31.1	30.2	35.3	34.2	32.8
15	32.4	30.4	30.4	36.9	34.9	33.8
16	33.0	31.3	30.5	35.2	34.5	33.4
17	33.2	31.1	30.3	36.8	34.1	32.5
18	33.5	31.7	30.7	36.5	33.6	31.2
19	32.4	30.9	29.8	38.5	35.7	33.8
20	33.6	31.6	30.4	35.7	33.6	31.7
21	33.3	30.8	29.9	36.5	34.1	32.9
22	33.6	31.4	30.2	35.9	33.7	31.9
23	33.7	31.3	29.6	36.5	34.1	32.7
24	33.4	31.4	30.4	34.7	32.4	31.2
25	33.9	31.7	30.1	37.4	33.9	32.2
26	33.1	31.0	29.4	36.4	33.2	31.4
27	32.3	31.1	30.1	34.8	32.5	30.8
28	33.7	30.6	29.7	33.9	32.1	30.3
29	32.1	31.3	30.5	34.7	32.5	31.1
30	33.4	32.1	30.3	34.4	32.3	30.8
Mean	33.09	31.27	30.21	36.77	34.44	32.67

*9th Sept 2014 to 8th Oct 2014.

during the reproductive period is given in Table 1 and 2. The range of temperature within the crop canopy in N-S direction was high (40.5°C to 30.3°C) as compared to E-W direction (35.7°C to 29.1°C) (Table 1). The mean temperature in N-S direction was 36.77°C at the bottom, 34.44°C at middle of vine and 32.67°C at top of vine, whereas in E-W direction it was 33.09 °C at the bottom, 31.27°C at middle of vine and 30.21°C at top of vine. The reduction in mean temperature in both the direction of sowing from bottom to middle and middle to top of vine correlated with increased in circulation of air and this might also be due to absorption of the short wave radiation at the top and middle of the crop canopy and the transmission of infra-red radiation to the bottom. These results are in agreement with the reports of Bisheshwor *et al.* (2013) in wheat where the canopy temperature recorded on E-W direction was significantly higher at all levels of different reproductive stages.

The light intensity on exposure side and shadow side within the crop canopy in E-W direction and N-S direction of sowing indicated that the light intensity in E-W direction was high 129.3 klux at 8:00 S., 950.0 klux at 12:00 noon and 430.2 klux at 4:00 S. in exposure side of the vine and 506.7 klux, 991.3 klux and 80.8 klux in shadow side of the vine, respectively, than N-S direction of sowing (both the side) (Table 2). In N-S direction, it was 97.2 klux at 8:00 S., 1053.5 klux at 12:00 noon and 384.2 klux at 4:00 S. in exposure side and 465.4 klux, 169.7 klux and 64.7 klux in shadow side of the vine, respectively. This high interception of PAR in the E-W direction may be due to the planting geometry of the plots and the solar elevation angle during the period on this location. The results are in agreement with finding of Jha *et al.* (2012) in mustard stated that the cumulated IPAR, RUE, biomass were found to be maximum in the broadcast plots followed by the E-W sown plots and N-S sown plots.

Table 2 Comparison of availability of light intensity (klux) in direction of sowing in bottle gourd cv. Pusa Naveen

Period	E-W Direction						N-S Direction					
	Exposure side (Front)			Shadow side (Back)			Exposure side (Front)			Shadow side (Back)		
	8:00 AM	12:00 NOON	4:00 PM	8:00 AM	12:00 NOON	4:00 PM	8:00 AM	12:00 NOON	4:00 PM	8:00 AM	12:00 NOON	4:00 PM
1	82.6	831.3	488	356.6	333.6	122.6	58.3	984.1	473.6	369.3	306.5	106.1
2	163.8	945.5	184.6	528.1	966.5	41	115	984.5	151.3	491	194.3	35.8
3	154.8	999.3	468.8	570	1094.3	82.1	116.1	1175.6	429.8	489.6	185.8	63.3
4	126.1	989	479.3	517	1057.3	89.8	98.6	1183	443.5	437.3	190.1	68.8
5	157.1	927.6	503.5	483.8	1032	98.3	145.3	1092	476.3	433.3	181.1	76.8
6	149.8	830.5	242.3	467.5	886.1	46.5	140	912.3	209.6	416.5	129	37.8
7	149.1	887	434.5	478.5	912.3	82.6	139.6	952.5	421.6	455.6	145.6	82.3
8	124.5	989.5	464.6	538.6	1071.8	90	94.5	1151.3	444	458.8	169.3	83
9	136.1	989.5	500.8	599	1078.3	86.8	104.3	1167.6	460.3	579	134.8	73
10	147.6	1008.5	483	536.8	1078.5	85.5	101.3	1147	421.1	506.6	181.3	70.8
11	141.1	997	443.6	549.5	1097.8	83.3	110.5	1179.1	406.8	464.8	195	74
12	146.6	1001.1	474.3	552.1	1057.5	86.3	108.8	1140.6	441.5	470.1	174.1	66.3
13	130.8	996.6	456	533.3	1084	83	103.1	1118.6	425.6	489	170.6	78
14	140.1	998.3	443.5	536.6	1076.5	85.5	100.5	1118.5	418.3	471.3	188.5	61.1
15	149.5	997	461.5	563.8	1057.8	82.8	102.1	1107.5	425.3	490.1	191	60.8
16	130.8	1016	448	517.3	913.5	93.6	98.1	932.5	429	458.5	130.1	69.3
17	120.3	1048.5	448	524.5	1087.6	88.8	98.5	1140	429.6	491.1	170.3	80.3
18	142	1023.8	449.6	529.1	1085.3	100	91.3	1134.1	417.1	495.3	170.3	67.5
19	136.3	1021.3	461.6	529.1	1088.8	78.3	83.6	1135	415.6	492	186.6	65.8
20	140.3	1018.5	473.5	525.8	1080.6	91.5	94.3	1166.8	416.5	488.1	156	65
21	141.1	1042.3	465	519.3	1029.8	84.8	87.5	1096.3	416.8	479.3	163.6	60.8
22	123	932.5	445	509.1	1046.8	69.1	95.6	1117.3	417.3	484.1	165.5	60.5
23	132.8	916.3	401.6	486	992.1	82.8	95.5	1020	342.5	481.6	161.3	55.5
24	117.5	899.3	421.1	491	975	82.5	91.5	1001.8	341.8	473.3	155.5	59
25	120	900.3	413.8	492.8	970.6	79.8	85	998.5	338.6	463.3	155.6	59.3
26	111.5	894	400.8	471	953	69.8	83.1	959.8	323.8	467.6	160	54.5
27	95	849.3	393.1	450.8	913.5	67	72.8	886.1	306	413.3	147	52.3
28	97.4	845.6	390.2	452.9	910.4	65.7	70.3	873.7	298.6	420.4	143	52.6
29	86.8	847.9	387.3	449.8	906.6	63.8	67.5	870.5	298.3	417.7	145.3	50.6
30	83.6	858.5	380.8	441.6	900.2	60.5	63.2	858.9	287.6	413.8	142.7	49.7
Mean	129.3	950.0	430.2	506.7	991.3	80.8	97.2	1053.5	384.2	465.4	169.7	64.7

*9th Sept 2014 to 8th Oct 2014.

Performance of growth characters

The data on growth characters (Table 3) revealed significant differences among direction of sowing at 45 DAS. The vine length (2.49 m), number of leaves/vine (25.23), leaf area (10425.17 cm^2), number of leaf nodes (25.23), number of primary laterals (8.13) and leaves on primary laterals (29.8) were significantly higher in E-W direction as compared to N-S direction which could be attributed to congenial environmental condition and significantly higher leaf area was attributed due to more number of primary laterals and leaves on primary laterals. Significantly higher number of leaves (42.13), leaf area (50792.33 cm^2), leaf nodes (42.13), leaf on primary laterals (81.96) and number of secondary laterals (5.16) were recorded in E-W direction at 55 DAS which might be due to the better interception of photosynthetically active radiation (PAR) and resulted to higher photosynthetic activity and assimilation of carbohydrates for increased plant growth. These results are in accordance with the findings of Abd EI Maksoud (2008) in maize, Haque *et al.* (2009) in bottle gourd and Akmal *et al.* (2013). Vine length, number of primary laterals per vine and leaf on secondary laterals showed at par performance among the direction of sowing at 55 DAS. At par performance in vine length at 55 DAS conformed to the finding of Bisheshwor *et al.* (2013) who reported that plant height is not affected by the row direction.

Table 3 Effect of sowing direction on growth characters in bottle gourd cv. Pusa Naveen

Characters	Direction of sowing		Level of significance
	E-W direction	N-S direction	
	Mean	Mean	
Characters at 45 DAS			
Vine length (m)	2.49	1.97	*
Number of leaves/ vine	25.23	20.10	*
Leaf area (cm^2)	10425.17	8727.33	*
Number of leaf nodes	25.23	20.10	*
Number of primary laterals/vine	8.13	5.43	*
Leaf on primary laterals	29.80	10.13	*
Characters at 55 DAS			
Vine length (m)	4.60	4.51	NS
Number of leaves/ vine	42.13	38.83	*
Leaf area (cm^2)	50792.33	34821.00	*
Number of nodes	42.13	38.83	*
Number of primary laterals/vine	10.06	9.03	NS
Leaf on primary laterals	81.96	69.43	*
Number of secondary laterals	5.16	3.43	*
Leaf on secondary laterals	11.70	8.43	NS

* Significant at (P=0.05), NS=non significant.

Performance of flowering traits

Significantly less number of days taken to anthesis of first male flower (49.53) and female flower (53.46) in E-W direction than N-S direction (50.10 and 55.86, respectively) was observed (Table 4). The less time taken to opening of male and female flower may be due to the congenial temperature in middle part of the vine (31.27°C), better growth and significantly higher leaf area at 45 and 55 DAS in E-W direction which might have resulted in higher photosynthesis and early switch over to the reproductive phase. The number of male flowers per vine was significantly higher in E-W direction (121.26) than N-S direction (102.6) but number of female flowers showed a reverse trend and was significantly higher in N-S direction (18.63) as compared to E-W direction of sowing (15.53). This could be due to the higher vegetative growth in E-W direction. High vegetative growth has inverse relationship on the reproductive phase of cucurbites in general. The sex ratio is observed comparatively lower in both the direction of sowing but significantly higher in E-W direction (7.8:1) as compared to N-S direction (5.5:1).

Performance of fruit attributes

The data on fruit attributes (Table 5) revealed that the number of fruits set per vine (4.4) and number of fruits developed to maturity (4.0) were significantly higher in E-W direction as compared to N-S direction (3.76 and 3.1, respectively). The higher fruit set and number of mature fruits per plant is attributed to the congenial temperature and higher light intensity which favoured better pollination in E-W direction. The results are in agreement with Marcelis *et al.* (2006) who have reported that 1% light increment results in higher fruit yield in vegetables. Number of rotten or disease fruits/vine were at par among the direction of sowing coupled with trailing which did not allow the fruits to come in contact with soil and water.

Table 4 Effect of sowing direction on flowering traits in bottle gourd cv. Pusa Naveen

Characters	Direction of sowing		Level of significance
	E-W direction	N-S direction	
	Mean	Mean	
Days taken to anthesis of first male flower	49.53	50.10	*
Days taken to anthesis of first female flower	53.46	55.86	*
Number of male flower/plant	121.26	102.60	*
Number of female flower/plant	15.53	18.63	*
Sex ratio (male:female)	7.8:1	5.5:1	*

* Significant at (P=0.05), NS = non significant.

Table 5 Effect of sowing direction on fruit attributes in bottle gourd cv. Pusa Naveen

Characters	Direction of sowing		Level of significance
	E-W Direction	N-S Direction	
	Mean	Mean	
Number of fruit set/vine	4.40	3.76	*
Number of mature fruit	4.00	3.10	*
Fruit rot per vine	1.00	1.25	NS
Fruit weight (kg)	2.55	2.05	*
Fruit length (cm)	49.89	47.09	*
Fruit width (cm)	9.81	9.32	*
Fruit cavity (cm)	7.28	7.15	NS
Cavity volume (cm^3)	2087.60	1904.80	*
Thickness of fruit wall (cm)	2.53	2.17	*

* Significant at (P=0.05), NS = non significant.

The fruit attributes, viz. fruit weight (2.55 kg), fruit length (49.89 cm), fruit width (9.81 cm), cavity volume (2 087.60 cm^3) and fruit wall thickness (2.53 cm) were significantly higher in E-W direction than N-S direction. Better fruit attributes in E-W direction may be due to better growth and development of vine which probably contributed to production and supply of more photosynthates to sink than in N-S direction of sowing.

Seed yield contributing characters

The results of seed yield contributing characters (Table 6) as influenced by direction of sowing showed that the number of seeds/fruit (753.9), number of filled seeds/fruit (682.75) and number of unfilled seeds (71.15) were at par in E-W as well as in N-S direction (692.12, 621.0 and 71.13, respectively). The statistically at par performance of these characters attributed the equal opportunity of pollination to the pollinators and possibly similar amount of ovules were fertilized. The significantly higher seed weight/fruit (107.06 g) and seed yield/vine (410.05 g) recorded in E-W direction could be attributed to better development of fruit attributes as compared to N-S direction. Similar results were also obtained for 100 seed weight. The results are in the conformity with that of Dipenbrock *et al.* (2001) in sunflower, Reza Monem *et al.* (2012) in mungbean and Jha *et al.* (2012) in mustard. The high seed yield (423.75 kg/acre) observed in E-W direction of sowing may be attributed to cumulative effect of significantly higher number of fruit/vine, more number of seed/fruit, seed weight/fruit, 100 seed weight and seed yield/vine in E-W direction than N-S direction (396.5 kg/acre). This is in agreement with findings of Wajid *et al.* (2007) in wheat, Abd-El Maksud (2008) in maize and Reza Monem *et al.* (2012) in mung bean.

Table 6 Effect of sowing direction on seed yield contributing characters in bottle gourd cv. Pusa Naveen

Characters	Direction of sowing		Level of significance
	E-W direction	N-S direction	
	Mean	Mean	
Number of seed/fruit	753.90	692.12	NS
Number of filled seed	682.75	621.00	NS
Number of unfilled seed	71.15	71.13	NS
Seed weight/fruit (g)	107.06	89.61	*
100 seed weight (g)	16.18	15.14	*
Seed yield/vine (g)	410.05	282.27	*
Seed yield/acre (kg)	423.75	396.50	

* Significant at (P=0.05), NS = non significant.

Seed quality attributes

The results of seed quality (Table 7) showed that germination (%) was at par among the directions of sowing and the at par performance of germination is attributed to better growing environment in both the direction of sowing. Seedling length (43.49 cm) and seedling dry weight (6.87 mg) were significantly superior in E-W direction as compared N-S direction. These could be attributed to the higher seed weight and availability of more food in the seed which was inturn resulted in higher seedling growth. The higher germination (%), seed coat weight, embryo weight, seedling length and seedling dry weight observed in seed produced form plants grown in E-W direction was responsible for significantly higher vigour index I (4247.37) and II (67.13) shown by these plants. Superiority in these traits might be due to the sound development of fruit and seed due to an early induction of male and female flower and more food reserve in embryo in E-W direction. Electrical conductivity of seed showed non-significant difference with respect to direction of sowing

Based upon the results recorded in this experiment it could be concluded that for exploitation of maximum light and optimum temperature for attaining better plant growth, fruit yield, seed setting, higher seed yield and quality

Table 7 Effect of sowing direction on seed quality attributes in bottle gourd cv. Pusa Naveen

Characters	Direction of sowing		Level of significance
	E-W direction	N-S direction	
	Mean	Mean	
Germination (%)	97.65	97.43	NS
Seedling length (cm)	43.49	41.82	*
Seedling dry weight (mg)	6.87	6.23	*
Vigour index I	4247.37	4074.76	*
Vigour index II	67.13	60.70	*
Seed coat weight (mg)	8.43	7.94	*
Embryo weight (mg)	7.79	7.21	*
Electrical conductivity (µmhos/cm/g)	92.20	105.05	NS

* Significant at (P=0.05), NS = non significant.

attributes, the seed production of bottle gourd cv. Pusa Naveen should be undertaken in E-W direction (over the trailing) during *kharif* season under Delhi condition.

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