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Consequence of umbel orders on flowering pattern, seed yield and seed quality parameters in onion cv.CO (On)5

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Abstract
A field experiment was undertaken to study the effect of umbel orders on flowering pattern, seed yield and seed quality parameters in onion. In this present investigation, Individual plant produces 10-12 umbels/plant, the flower stalk of first order umbel emerged at 35 days after sowing (DAS) and it was extended over a period of 69 DAS for emergence of last order umbel. The flowering initiated in the first order umbel on 63 DAS and it reached 50% flowering on 66 DAS and completed on 69 DAS. Where as in last order umbel flowering started on 92 DAS and reached 50% on 94 DAS and completed on 97 DAS. The days for attainment of physiological maturity by the first and last order umbels were 112 and 137 respectively. The quantitative and qualitative parameters were reduced as the umbel order increased. The maximum values of quantitative characters *viz.*, umbel diameter (5.3 cm), umbel fresh weight (3.81 g), umbel dry weight (2.07 g), total number of capsules (94.6), number of filled capsules (50.8), seed set (53.6%); and qualitative characters viz., germination (88%), speed of germination (21.6), root length (6.0 cm), shoot length (9.1 cm), dry matter production (16.5 mg seedling^{-10}) and vigour index-I (1333) were recorded up to seventh order umbels. After that, drastic reductions were observed in both quantitative and qualitative parameters. Hence it could be recommended that up to seven umbels plant^{-1} to be retained for the harvest of more quantity of high quality seeds in onion.

Keywords: Umbel orders, flower stalk, physiological maturity, seed yield, seed quality

1. Introduction

Onion (*Allium cepa* L.) is an important spice crop cultivated all over the world. It is also used as a vegetable and salad; and has preservative and medicinal values. Onion is widely used to increase taste of different types of food and curries. It grows in almost all the states of India as a rabi crop. The total area under onion cultivation is 1.27 million hectare and its production is about 21.56 million tons. The average productivity is 10.18 tons ha^{-1}. In the world, India ranked second in cultivated area, production and export next to china. In India, Maharashtra state has the prominent position in respect to onion production, accounting 37.12% of area and 31.4% of national production (Horticultural statistics at a glance, 2016) [12].

Two types of onion *viz.*, common onion and aggregatum onion are commercially important. The common onion type, *Allium cepa var. cepa* produces single large bulb and propagated through seeds. The aggregatum onion *Allium cepa var. aggregatum* produces small bulbs which form an aggregated cluster and propagated through bulblets.

Normally aggregatum onion varieties do not flower and set seed; hence, it propagated through bulblets. The major constraint in cultivation of aggregatum onion is large quantity of seed bulbs are needed for planting. The cost of the planting material occupies 50% of the total production cost. The alternative way to reduce the cost of production is using seed as planting material. The onion variety CO (On) 5 is a seed propagated variety of aggregatum type; it was utilized in the present study.

Onion is biennial crop storing food in bulbs during the first season and flowering in the second season. It express indeterminate flowering behavior and in its blooming stage it produces flower stalk that contains at a tip an inflorescence known as primary umbel or first order umbel and subsequently produces, second, third, fourth order umbels and up to a maximum of twelve order umbels under favorable climatic and soil conditions. The number of umbels per plant mainly depends on management practices. More number of umbels plant^{-1} resulted in reduction of seed yield and quality (Geetharani, 2005) [10].

Flowering is a crucial phenological phase in onion as it greatly influenced the seed yield. Onion plant produces different orders of umbels *viz.*, first order, second order, third and nth order, which emerge at different stages of plant growth (Figure 2). The growth and development pattern of umbels depend on the time of initiation. Based on our preliminary study, heterogeneity in seed quality was observed in onion which is mainly due to variations between the umbels of different orders within the mother plant. Generally, seeds from the first order umbel are heavier than those of later order umbels. In most of the vegetable crops, due to longer period of flowering and ripening, early formed seeds differ from later formed ones in quality due to exposure to different environmental conditions like air, temperature, moisture stress and also differential supply of essential nutrients and accumulation of photo assimilates (Ovcharov and kisilova, 1996) [22] resulted considerable variation in seed size and quality within the same plant (Whalley *et al*., 1966) [35].

The phenology of seed propagated aggregatum onion cv. CO (On) 5 has to be studied to determine the quality of seeds in different umbel orders. Hence, the study was conducted to assess the flowering pattern with reference to umbel production and their influence on seed yield and quality, to determine the optimum umbel number for harvesting high quality seeds.

2. Materials and Methods

A field experiment was undertaken at Department of Vegetable Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during rabi (2017-18). The experiment was laid out in randomized block design with 4 replications (Figure 1). All the recommended packages of practices were adopted. Ten plants were selected randomly from each plot and the following observations on quantitative and qualitative parameters were observed and mean values were calculated.

The observations on number of days taken for flower stalk initiation, spathe (a large sheathing bract (paper like structure) enclosing the flower cluster) opening, initiation of flowering, 50% flowering, completion of flowering and physiological maturity from date of bulb sowing were recorded in first, second, third and n^{th} order umbels. The umbels of first, second, third and n^{th} order were harvested at physiological maturity and the diameter (measured with a scale by keeping it across the stalk at the middle portion of the umbel), fresh weight and dry weight (sun drying for two days) of the umbels were taken. The total number of capsules, number of filled capsules and number of ill filled capsules umbel^{-1} were counted in the harvested umbels, from this value the seed set percentage was calculated by using following formula.

$$\text{Seed set (\%)} = \frac{\text{Number of filled capsules umbel}^{-1}}{\text{Total number of capsules umbel}^{-1}} \times 100$$

After threshing and cleaning the total number of seeds umbel^{-1} was counted and then graded by using 6/64" round perforated metal sieve and counted the number of undersized seeds umbel^{-1}. The seeds obtained from individual umbels were weighted and expressed as seed yield umbel^{-1}(g).

Seeds obtained from individual umbel were assessed for germination (ISTA, 2013) [14], root and shoot length; and dry matter production of 12 days old seedlings. Seedling vigour index was computed by adopting the formula as suggested by Abdul-Baki and Anderson (1973) [1] and expressed in whole number.

Seedling vigour index = Germination (%) x Seedling length (cm)

2.1. Statistical analysis

The data collected from the experiment was analyzed statistically adopting the procedure described by Panse and Sukhatme (1985) [24]. Wherever necessary, the per cent values were transformed to angular (Arc-sine) values before analysis. The critical differences (CD) were calculated at 5 per cent (P= 0.05) probability level. If the F test is non-significant it was indicated by the letter NS.

3. Results and Discussion

As said earlier onion produces umbels of different orders in mother plant and days for flower stalk initiation, spathe opening, initiation of flowering, 50% flowering, completion of flowering and attainment of physiological maturity varied with each order (Figure 3a, 3b and 3c).

In the present study, the observation on flowering pattern in onion revealed that the flower stalk production ranged over a period of 34 days, where the first flower stalk appeared on 35 days after sowing (DAS) and subsequently with an interval of two to four days remaining flower stalks (2 to 11) were initiated and last flower stalk (12) was produced on 69 DAS. The spathe opening of umbels started from 53 DAS and completed on 82 DAS (Table 1). The flower opening started within 63 to 69 days in first three umbel orders and within 72 to 78 days in four to seventh order umbels and within 81 to 92 days in eight to twelfth order umbel. The umbel order of first and second attained 50% flowering within 68 DAS and for third to sixth order it was 79 days and for eighth to tenth order it was 88 days and a maximum range of 90 to 94 days for eleventh and twelfth order umbel respectively (Table 1). The flowering period completed shortly in first order umbel (69 DAS) followed by second to fourth order umbel (73 to 79 DAS) where as it was extended to 91 to 97 DAS in tenth to twelfth order umbel (Table 1).

The physiological maturity was reached on 121 DAS in first four umbel orders and it was extended up to 128 to 137 DAS for last five order umbels (7 to 12) (Table 1). Differential date of flower stalk initiation in different umbel orders leads to differential date of maturity. Sundaralingam (1995) [33] and Akilan (1986) [2] reported that variations in maturation of different umbel orders in carrot and coriander, respectively.

The umbel diameter decreased gradually with increasing umbel orders. It ranged from 6.2 to 4.4 cm for first order umbel to twelfth order umbel. The first two umbel orders produced large sized umbels (6.2 and 6.1 cm, respectively), third to seventh order umbel size ranged with 6.0 to 5.1 cm and minimum range of 4.9 to 4.4 cm was recorded by the umbel orders of nine to twelve (Table 1). The fresh and dry weight of umbel ranged at higher level for the umbel of first seven orders (4.91 and 3.77 to 3.81 and 2.07 g respectively) and it reduced gradually, and minimum weights were recorded by ninth to twelfth order umbels (3.49 and 1.55 to 3.15 and 0.91 g respectively). Similarly, the number of capsules decreased gradually with increasing umbel orders and more than hundred capsules were produced by first five order umbels (105.5 to 137.3) and it was 94.6 for the seventh order umbel. Less number of capsules was produced by eleventh (58.6) and twelfth order umbel (49.3) (Table 1). Photosynthetic assimilates accumulated were effectively utilized by the early formed umbels, resulted in complete development of umbel.

Seed set percentage decreased as the umbel order increased. It ranged from 78% to 43% for first to twelfth order umbel. It was higher for the first three umbel orders (78, 76 and 72%) and with a range of 68 to 51% were recorded by fourth to eighth order umbels, the umbels of remaining orders (9 to 12) produced very low range of seed set (48 to 43%) (Figure 4). Similarly in mung bean, early-formed flowers had higher pod set and retention capacity than later-formed ones (Fakir *et al*., 2011) [9]. Spollen *et al*. (1986) [32] reported in soybean, the early formed flowers had a higher pod set than the later; this might be due to that most of the carbohydrates produced by the leaf are used for filling of early formed pods. Saitoh *et al*. (1999) [28] also reported that in soybean with increasing number of flowers per raceme reduced the rate of pod set. Mondal *et al*. (2011a) [18] reported that the assimilates sink strength of early formed pods will be greater than the later

formed ones and helps in producing higher rate of pod set in mungbean. Rachis diameter and radial length of xylem and phloem and vascular tissues decreased at the distal end (contains late formed flowers) of raceme compared to proximal one (Mondal *et al*., 2011b) [17]. These results suggested that phloem was poorly developed in the distal part of the raceme and thus providing possibly inadequate amount of photosynthate to the later formed flowers/pods. Similar results were also found in soybean (Wiebold and Panciera, 1990) [36], in lignosus bean (Bari and Prodhan, 2001) [3] and in pigeonpea (Begum *et al*., 2007) [4]. That is why earlier formed umbels had a higher seed set than the latter formed umbels. The maximum total number of seeds and filled seeds percentage were recorded by first seven order umbels (426.5 to 81.8 and 96% to 51% respectively) and from eighth order, total number of seeds and filled seeds percentage were reduced drastically. The minimum total number of seeds (37.2 to 23.7) and filled seeds percentage (38 to 11%) were produced in the last three umbel orders (9 to 12). Proportions of filled seeds were more than the undersized seeds up to seventh order umbels and number of undersized was less in first order umbel (17.3). From eight to twelfth order the proportion of undersized seeds were more than the filled seeds. The undersized seeds percentage was increased as the umbel order increased. It was recorded minimum in first six order umbels (4 to 25%). It drastically increased after sixth order umbels; it ranged from 49% to 89% for seventh order umbel to twelfth order umbel (Table 2) (Figure 4). The number, size and weight of carrot seeds, which determine the seed quality, vary according to the umbel order (Rodo *et al*., 2001) [27]. Illipronti *et al*. (2000) [13] also confirmed that, seed yield and quality variation in soybean with reference to primary and secondary branches. Early formed flowers having more time for assimilate accumulation and this attain more sink strength than the later-formed flowers (Mondal and Hamid, 1998; Saitoh *et al*., 2004; Biswas *et al*., 2005) [16, 29, 5].

The seed yield of umbels were maximum with first two umbel orders (1.463 and 1.348 g) and optimum range was recorded by the umbel order of three to seven (0.884 to 0.218 g) and the remaining umbel orders (8 to 12) recorded very low range of yield (0.189 to 0.047 g) (Table 2). Early formed umbel orders produced seeds of maximum size and weight. This may be due to the translocation of most of the assimilates to first formed umbels than the late formed umbels. Earlier-formed pods were heavier than the later-formed ones (Kuroda *et al*., 1998; Begum *et al*., 2007; Mondal *et al*., 2011a) [15, 4, 18], it indicating inadequate assimilate supply to later formed pods. Similar result was reported by Blomquist and Kust (1971) [6] in soybean. In carrot, primary and secondary umbels have developed larger seeds than those from the high order umbels (Corbineau *et al*., 1995) [8]. Other authors (Satyaveer *et al*., 1994, Shantha *et al*., 1999) [30, 31] also established the same information. Nascimento (1991) [21] observed that primary umbel of 'Brasília' carrot contributed to 11%, secondary to 58% and tertiary to 31% of the total seed production. Illipronti *et al*. (2000) [13] concluded that more seeds were harvested from primary branches and secondary branches in soybean. Renugadevi (2004) [26] in cluster bean reported that the variation in period of flower initiation and attainment of maturity influenced the seed yield and quality and 40% higher yield was recorded by the first formed pods than the later formed pods.

Germination percentage was higher in early formed umbel orders, and it was decreased as the umbel order increased. Highest seed germination percentage was recorded by first and second order umbels (9%) followed by third and fourth order umbels (9%) and was minimum by twelfth order umbel (84%) (Table 2). It indicates that, seeds of early formed umbels possess high food reserves, so it produces more vigorous seedling than the seeds of late formed umbels. The carrot seeds from primary and secondary umbels had higher percentages of germination capacity than those from the high order umbels (Corbineau *et al*., 1995) [8]. Other authors (Szafirowska, 1994; Satyaveer *et al*., 1994; Shantha *et al*., 1999; Panayotov, 2010) [34, 30, 31, 23] also established the same information.

As the number of umbel order increased, reduction in all seed quality parameters was recorded. The root and shoot lengths recorded highest in first order umbel (6.3 and 9.3 cm) followed by second order umbel (6.2 and 9.3 cm) and the lowest was in twelfth order umbel (5.6 and 8.7 cm). The drymatter production umbels. It declined from 17.5 was maximum up to eighth order umbel compared to remaining mg seedling^{-10} to 15.7 mg seedling^{-10} with respect to first order umbel to twelfth order umbel. Highest vigour index was recorded in first order and second order umbel (1422 and 1416). The lowest vigour index was recorded in twelfth order umbel (1205) (Table 2). Carvalho and Nakagawa (1983) [7] reported in carrot that seeds from superior umbel orders have higher size and density, presenting a better seed development. Seeds with fully mature embryos and high amounts of reserves are potentially the most vigorous ones. Seeds from the medium or upper third tended to have a lower 100 seed weight, inferior germination, and higher electrical conductivity, indicating low vigour in soybean (Hampton *et al.*, 1996) [11]. Pereira *et al.* (2008) [25] in carrot reported that the seeds of primary and secondary umbels performed better than those from tertiary umbels. Seeds from king umbels had higher quality than those from secondary ones in carrot (Muniz, 1999; Muhammad and Anjum, 2001) [20, 19].

Fig 1: Field view of the experimental plot

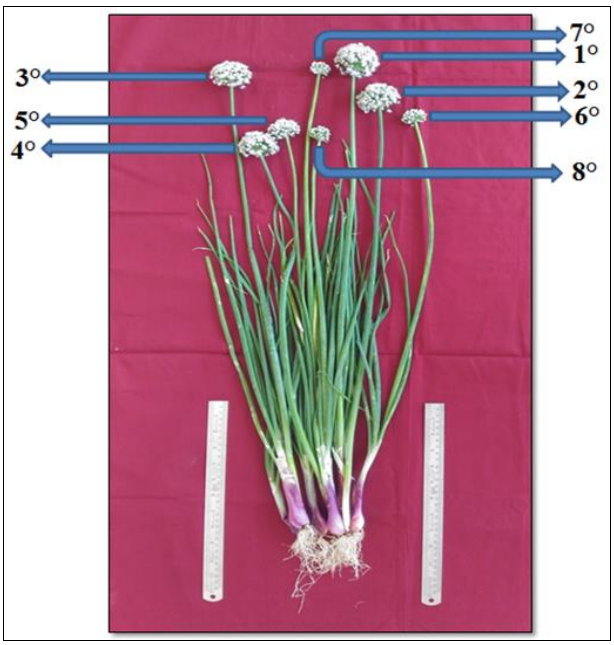

Fig 2: Different order umbels in a single plant (1° - First order umbel; 2° - Second order umbel; 3° - Third order umbel; 4° - Fourth order umbel; 5° - Fifth order umbel; 6° - Sixth order umbel; 7° - Seventh order umbel; 8° - Eighth order umbel)

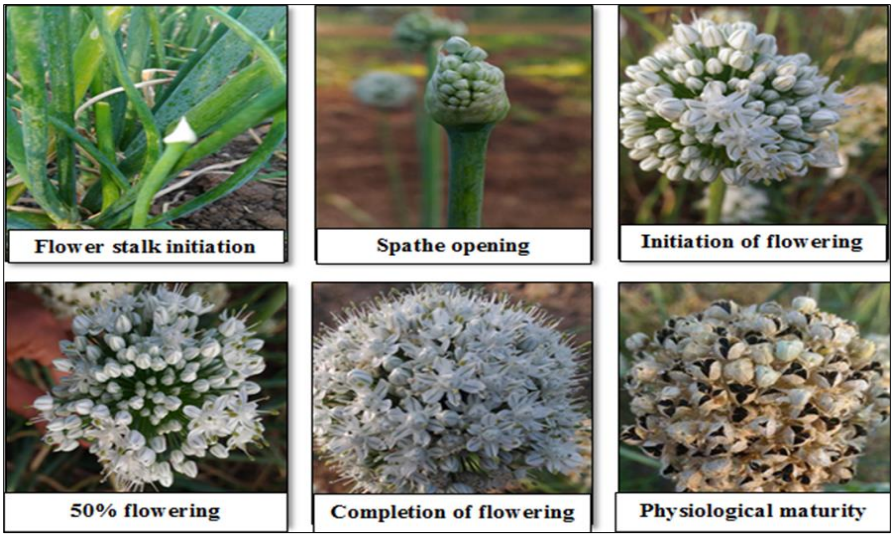

Fig 3a: Different stages of umbel development

Fig 3b: Different growth stages of umbel development

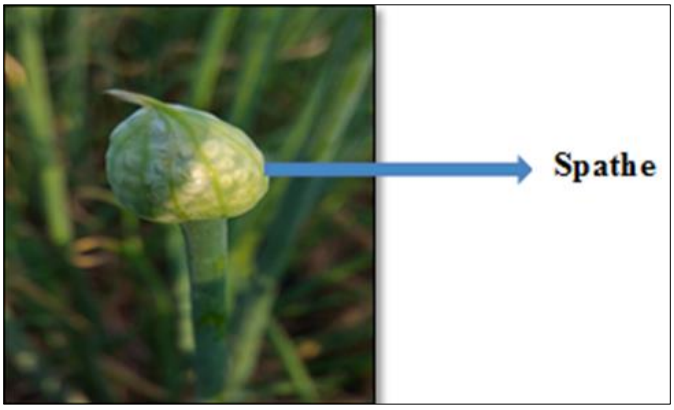

Fig 3c: Spathe (a large sheathing bract (paper like structure) enclosing the flower cluster)

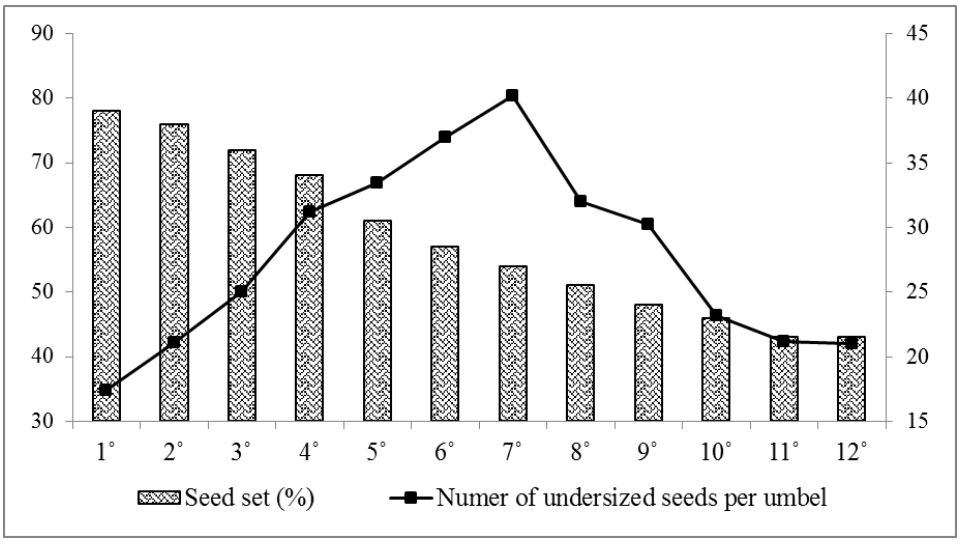

Fig 4: Seed set (%) and number of undersized seeds per umbel in different umbel orders

Table 1: Flowering pattern, umbel and capsule characters in different umbel orders

Umbel orders	Flowering pattern						Umbel and capsule characters			
	Days for flower stalk initiation (DAS)	Days for spathe opening (DAS)	Days for initiation of flowering (DAS)	Days for 50 per cent flowering (DAS)	Days for completion of flowering (DAS)	Days for physiological maturity (DAS)	Umbel diameter (cm)	Umbel fresh weight (g)	Umbel dry weight (g)	Number of capsules umbel^{-1}
1˚	35.3	52.5	62.8	65.6	69.3	112.4	6.2	4.9	3.8	137.3
2˚	39.6	55.7	65.2	68.0	72.5	115.3	6.1	4.7	3.4	131.5
3˚	42.4	58.1	68.5	71.5	75.9	118.5	5.9	4.6	3.2	123.4
4˚	46.9	61.4	71.9	74.3	78.5	120.9	5.8	4.4	3.0	116.4
5˚	48.6	63.4	72.9	75.8	80.4	121.3	5.6	4.3	2.7	105.6
6˚	52.3	66.9	75.0	78.5	83.0	124.8	5.5	4.2	2.5	99.2
7˚	55.2	69.6	78.4	81.1	85.6	126.6	5.3	3.8	2.1	94.6
8˚	58.6	72.4	81.3	84.9	87.3	128.4	5.1	3.7	1.8	82.4
9˚	60.9	73.6	82.5	85.7	88.9	129.4	4.9	3.5	1.6	75.6
10˚	64.8	77.3	85.9	88.4	91.7	131.6	4.8	3.4	1.3	67.6
11˚	66.1	79.8	87.6	90.2	93.5	132.1	4.5	3.2	1.1	58.6
12˚	69.3	81.6	92.0	94.3	97.3	136.9	4.4	3.2	0.9	49.3
Mean	53.4	67.7	77.0	79.9	83.7	124.9	5.4	4.0	2.3	95.1
SEd	1.199	1.581	1.968	1.380	1.619	2.533	0.101	0.079	0.035	2.420
CD (P=0.05)	2.487	3.280	4.081	2.861	3.358	5.254	0.210	0.164	0.073	5.019

Table 2. Seed yield and physiological seed quality parameters in different umbel orders

Umbel orders	Yield characters				Physiological seed quality characters				
	Number of seeds umbel^{-1}	Filled/ Good seed percentage	Undersized seed percentage	Seed yield umbel^{-1} (g)	Germination (%)	Root length (cm)	Shoot length (cm)	Dry matter production (mg seedlings^{-10})	Vigour index
1˚	426.5	96 (78.47)	4 (11.54)	1.463	91 (72.54)	6.3	9.3	17.5	1422
2˚	395.3	95 (77.08)	5 (12.92)	1.348	91 (72.54)	6.2	9.3	17.3	1416
3˚	264.7	91 (72.54)	9 (17.46)	0.884	90 (71.57)	6.2	9.2	17.3	1397
4˚	235.2	87 (68.87)	13 (21.13)	0.770	90 (71.57)	6.2	9.2	17.1	1385
5˚	190.3	82 (64.90)	18 (25.10)	0.609	89 (70.63)	6.1	9.1	16.8	1367
6˚	145.9	75 (60.00)	25 (30.00)	0.448	88 (69.73)	6.1	9.1	16.8	1348
7˚	81.8	51 (45.57)	49 (44.43)	0.218	88 (69.73)	6.0	9.1	16.5	1333
8˚	69.4	54 (47.30)	46 (42.71)	0.189	87 (68.87)	6.0	9.0	16.3	1313
9˚	66.7	55 (47.87)	45 (42.13)	0.182	87 (68.87)	5.9	8.9	16.1	1297
10˚	37.2	38 (38.06)	62 (51.94)	0.091	86 (68.03)	5.9	8.9	15.9	1276
11˚	27.8	24 (29.33)	76 (60.67)	0.061	85 (67.22)	5.7	8.8	15.8	1243
12˚	23.7	11 (19.37)	89 (70.63)	0.047	84 (66.42)	5.6	8.7	15.7	1205
Mean	163.7	63 (52.54)	37 (37.47)	0.526	88 (69.73)	6.0	9.0	16.6	1333
SEd	3.877	1.328	0.964	0.013	1.800	0.127	0.179	0.367	33.516
CD (P=0.05)	8.039	2.754	1.999	0.026	3.732	0.263	0.371	0.760	69.507

4. Conclusion

Thus, the present study clearly revealed that up to seventh order umbel, the yield characters viz., umbel diameter (5.3 cm), umbel fresh weight (3.8 g), umbel dry weight (2.1 g), total number of capsules (94.6) and seed set (54%) were found to be optimum, whereas drastic reduction in all the parameters were recorded in the remaining umbel orders. Similarly, the seed quality parameters were also found to be at higher level up to seventh order umbel. The seed quality characters viz., germination (88%), root length (6.0 cm), shoot length (9.1 cm), dry matter production (16.5 mg seedlings^{-10}) and vigour index (1333) were found to be higher than the later formed umbels.

Hence in order the first formed umbels of up to seventh order recorded maximum quantity of quality seeds, thereafter the quantity of quality seed produced by the later formed umbels were very much reduced. The retention of seven order umbels plant^{-1} could be recommended for the maximum recovery of high quality seeds.

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