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Effect of Sowing Dates and Harvesting Dates on Germination and Seedling Vigor of Groundnut (*Arachis hypogaea*) Cultivars

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ABSTRACT

Groundnut exhibits indeterminate growth habit resulting in seeds of varying sizes and maturity at harvest and probably there may also be differences in quality. Even under sub-optimal conditions, 20-30% seeds either do not germinate or fail to develop into healthy seedlings due to loss in seed vigor resulting in poor plant stand in the field. Laboratory experiment was carried out to determine the quality of seeds of SG 99 (Spanish bunch type) and M 522 (semi-spreading) cultivars grown in field on 4 sowing dates (25 April, 10 May, 25 May and 10 June) and harvested at 3 different stages (120, 135, 150 days after sowing). Studies were initiated three months after each harvesting date to overcome seed dormancy. Significant variations were recorded in the two cultivars for most of the parameters studied (germination, moisture, fresh weight, dry weight, seedling length, vigor index). Sowing and harvesting dates significantly influenced some of these parameters. Delay in sowing from 25 April to 10 June reduced 100 kernel weight and oil content but marginally increased shelling out turn. Maximum dry matter at physiological maturity was accumulated by crop harvested at 135 days after sowing (DAS). Overall, seeds of crop harvested at 135 DAS had significantly higher mean germination (91.3%), seedling length (8.8 cm), dry matter (0.090 g) and vigor index I (806.4). Bunch type cultivar (SG 99) surpassed the semi-spreading cultivar (M 522) in almost all the germination related traits and vigor index.

Key words: Physiological maturity, seed quality, moisture, kernel, dry matter, oil content

INTRODUCTION

Seed development occurs in the period between fertilization and maximum fresh weight accumulation. Seed attains maximum dry weight at physiological maturity even though the maturation of seed commences at the end of seed development and continues till harvesting of the crop (Mehta *et al*., 1993). Knowledge of seed development and physiological maturity helps to harvest the crop at appropriate time and ensures seed quality in terms of germination and vigor. Seeds harvested prior to attainment of physiological maturity remain immature, under developed and store less food reserve as compared to those harvested at physiological maturity (Singh and Lachanne, 1995; Deshpande *et al*., 1991). Seed harvested at physiological maturity is considered to have maximum viability and vigor (Nautiyal *et al*., 2010). Physiological maturity in seeds is a genotypic character but its attainment is also influenced by environmental factors (Kole and Gupta, 1982; Mahesha *et al*., 2001a; Khatun *et al*., 2009).

Groundnut is an important legume oilseed crop grown in about 100 countries in the subtropical and tropical regions representing all the continents of the world except Antartica (FAO, 2012). The high oil content in groundnut seeds (45-55%) makes it more perishable and prone to rapid quality deterioration and loss in viability (Perez and Arguello, 1995). Since groundnut is indeterminate in growth habit, the harvested seeds are often from varying maturity stages. Indeterminacy has been observed more in case of Virginia (*A. hypogaea* ssp. *hypogaea* var *hypogaea*) cultivars than Spanish (*A. hypogaea* sp. *fastigiata* var. *vulgaris*) cultivars (Nautiyal *et al*., 1990; Sardana and Sharma, 2009). Sowing of such harvested seeds representing different maturity stages often results in failure of 20-30% seeds to germinate or develop into healthy seedlings (Devi *et al*.,1999; Nautiyal *et al*., 2010). This contributes to formation of a patchy crop stand and consequent loss of yield (Nautiyal *et al*., 1990, 2010). Groundnut is mainly grown in many parts of the world including India, under rain fed conditions on poor fertility, light texture soils of poor moisture retention capacity. Under such sub-optimal conditions, poor seed quality not only delays the onset of germination but also reduces the final crop stand through inherent low seed vigor. Reports on the effect of seed size on germination, field emergence, productivity and variation in crop stand in groundnut are available in literature (Singh *et al*., 1998; Devi *et al*., 1999; Sardana and Sharma, 2009). Understanding of mutual relations between the physiological processes associated with seed maturity, attributes of seed and seedling vigor may help to enhance field emergence and attain uniform crop stand; but these processes are yet to be fully understood in groundnut. The objective of the study was to investigate the influence of seed maturity stages of groundnut which was sown on different dates, on seed germination and seedling vigor.

MATERIALS AND METHODS

Study site: The field experiment followed by laboratory experiment was conducted during summer 2007 at the Punjab Agricultural University, Ludhiana, India. The experimental site is situated at 30°54'N latitude, 75°48'E longitude and 247 m above mean sea level.

Field experiment: Field experiment was conducted on loamy sand soil (Typic ustochrept) which was low in organic carbon and available nitrogen and medium in available phosphorus. Treatments consisted of 4 sowing dates (25 April, 10 May, 25 May and 10 June) in the main plots and combinations of 2 cultivars (SG 99 and M 522) and 3 harvesting dates (120, 135 and 150 days after sowing) in the sub plots as per split plot design of experimentation and were replicated four times. Cultivar SG 99 is a Spanish bunch type (*Arachis hypogaea* L. subsp. *fastigiata var vulgaris*) whereas cultivar M 522 is semi-spreading (*Arachis hypogaea* L. subs. *hypogaea var. hypogaea*) in growth habit. Each plot comprised twelve rows, each of 4.5 meter length and row spacing of 30 cm (Anonymous, 2012). Plant to plant spacing within row was maintained at 15 cm in case of SG 99 and 22.5 cm for M 522. The crop was sown on different dates (as per treatments) using 100 kg kernels per hectare. The kernels were pre-treated with Thiram @ 5 g kg^{-1} kernels to ward off seed borne diseases (Sardana and Sharma, 2009). Nitrogen @ 15 kg ha^{-1} in the form of urea (46% N) and phosphorus @ 20 kg P_2O_5/ha in the form of single super phosphate (16% P_2O_5) were applied at time of sowing. All other recommended agronomic practices were adopted (Anonymous, 2012) to raise good crop.

After the harvest of crops on prescribed dates, shelling percentage, 100 kernel weight and oil content were determined. For shelling out turn, a representative sample of 500 g of pods was hand shelled and the kernels so obtained were weighed. From the lot of kernels obtained after shelling, 100 kernels were taken at random and weighed to find out 100 kernel weight. The oil content in kernels was estimated by using Nuclear Magnetic Resonance (NMR) spectroscope, Newport Analyzer Model MK IIIA (Alexander *et al.*, 1967).

Laboratory experiment: Pod samples were collected from each treatment plot from three replications for laboratory studies. The laboratory studies were initiated three months after harvesting to alleviate dormancy. The pods were hand threshed one day prior to setting up of the experiment. Each sample obtained from field study was replicated twice, making six replications per treatment. Twenty five kernels were picked up at random from the lot of threshed sample of each treatment. For germination studies seeds were surface sterilized with 1% mercuric chloride and placed on germination towels and incubated at 25±1°C in growth chamber with 60% relative humidity. Seedling emergence was recorded daily up to 10 days. Germination recorded was expressed on percent basis.

Germination percentage, speed of germination, seedling length, fresh weight and dry weight of seedlings were recorded after 10 days as per ISTA (1996).

Germination percentage:

$$n/N\times100$$

where, n is the number of germinated seeds, N is the number of total seeds.

Speed of germination:

$$\sum D\times n/N$$

where, n is the number of germinated seeds at each day; D is the number of days after the start of the experiment.

Seedling length: After the termination of experiment, five seedlings were randomly selected from each replicate. Total seedling length was measured with the help of a scale in cm.

Fresh weight and dry weight of seedlings: After measuring the seedling length, seedlings were weighed for recording fresh weight. Then the seedlings were put into paper packet separately and placed into the preheated oven (70°C) for 48 h. After cooling, the dry weight was taken.

Moisture content: Moisture content in the seedlings was computed by the standard protocol (ISTA 1996).

Seedling vigour index: It was determined according to the formulae given by Reddy and Khan (2001).

$$\text{Vigor index I} = \text{Percent germination}\times\text{seedling length}$$

$$\text{Vigor index II} = \text{Percent germination}\times\text{seedling dry weight}$$

Statistical analysis: The treatments were subjected to the least significant differences (LSD at 0.05) as per split plot design of experiment using statistical software SAS (2008) to compare the effects of sowing dates, harvesting dates and cultivars and their interactive effects on 100 kernel weight, shelling out turn, oil content and seedling characteristics (moisture content, germination, speed of germination, seedling length, fresh and dry weights and vigor of seedlings). Sowing dates comprised the main plot treatments and combinations of cultivars and harvesting dates as sub plot treatments. The treatments were replicated six times. The correlation co-efficient tests were conducted for different variables (moisture content, percent germination, speed of germination, seedling weight on vigour index) wherever needed.

RESULTS AND DISCUSSION

Seed characteristics: Cultivar M 522 registered significantly (LSD 0.05 = 1.61) higher 100 kernel weight than SG 99 (Table 1a). The shelling out turn of SG 99 was conspicuously (LSD 0.05 = 1.14) higher than M 522 (Table 1a). There was not much difference in oil content in SG 99 (50.5%) and M 522 (50.6%). Cultivar M 522 produced 9.9% higher mean 100 kernel weight than SG 99 but the shelling out turn of SG 99 was 12.9% higher than M 522. Variation in seed weight was more in Virginia as indicated by coefficient of variation (7.1%) than the Spanish cultivars (3.2%) which further could be due to indeterminate growth habit of the former type (Nautiyal *et al*., 2010). Pod, kernel size and shelling out turn are genetic characters and environmental conditions have little influence on these traits. Cultivar M 522 is a bold seeded variety (Anonymous, 2012). In earlier studies also conducted at the same location, shelling out turn of SG 99 was significantly higher but 100 kernel weight significantly lower than M 522 (Sardana and Kandhola, 2007; Sardana *et al*., 2008). At some other locations also, differences in yield attributes and production potential of semi-spreading and bunch type varieties of groundnut have been reported (Ahmed, 1992; Patel *et al*., 1998).

There was consistent reduction in 100 kernel weight (LSD 0.05 = 3.04) and oil content (LSD 0.05 = NS) with delay in sowing from 10 May (55.0 g, 51.3%) to 25 May (52.5 g, 50.7%) to 10 June (45.5 g, 49.7%). Reduction in 100 kernel weight in 10 June sowing date over 25 May sowing date was significant (Table 1b). Delay is sowing up to 25 May resulted in non-significant but consistent increase in shelling out turn (Table 1b).

Groundnut is a tropical crop. Higher temperature and increased sunshine hours during major part of the vegetative growth period leads to greater accumulation of resources whereas adequate

Table 1a: Seed characteristics of groundnut cultivars

Cultivars	100 kernel weight (g)	Shelling (%)
SG 99	49.5^b	65.4^a
M 522	54.4^a	57.9^b

Values with different letters are significantly different at p = 0.05

Table 1b: Seed characteristics of groundnut cultivars as influenced by sowing dates

Dates of sowing	100 kernel weight (g)	Shelling out turn (%)	Oil (%)
25 April	54.7^a	60.1	50.5
10 May	55.0^a	61.7	51.3
25 May	52.5^a	62.5	50.7
10 June	45.5^b	62.2	49.7

Values with different letters are significantly different at p = 0.05

Table 1c: Seed characteristics of groundnut cultivars as influenced by sowing dates

	Cultivars					
	100 kernel weight (g)		Shelling out turn		Oil (%)	
Dates of sowing	SG 99	M 522	SG 99	M 522	SG 99	M 522
25 April	53.1[b]	56.4[a]	64.6[b]	55.6[e]	50.4[a]	50.6[a]
10 May	52.5[b]	57.5[a]	65.5[ab]	58.0[d]	51.4[a]	51.2[a]
25 May	52.1[b]	52.9[b]	65.0[ab]	60.1[c]	50.6[a]	50.8[a]
10 June	40.2[d]	50.7[c]	66.4[a]	58.1[d]	49.8[a]	49.6[a]

Values with different letters are significantly different at p = 0.05

Table 1d: Effect of harvesting dates on seed characteristics of groundnut

Date of harvesting (days after sowing)	100 kernel weight (g)	Shelling (%)
120	48.7[b]	60.4[b]
135	53.2[a]	60.9[b]
150	53.9[a]	63.8[a]

Values with different letters are significantly different at p = 0.05

moisture availability through rains resulting in higher relative humidity during post anthesis period helps in the development of larger sink and efficient utilization of resources during reproductive phase. Sardana and Kandhola (2007) and Sardana *et al.* (2008) reported consistent reduction in 100 kernel weight and increase in shelling out turn of different cultivars of groundnut with delay in sowing. Prasad *et al.* (2000) reported decline in 100 kernel weight with increase in soil temperature particularly during post peg development phase. Delayed sowing led to reduced vegetative and reproductive phases and hastened maturity resulting in insufficient time for proper development of pods. The maximum temperature during crop growth period decreased from May onwards whereas the minimum temperature was lower in May than June to August and decreased in subsequent months. Relative humidity (both morning and evening) was lowest in May and increased during rainy season of June to August and decreased again in September- October.

Delay in sowing decreased the 100 kernel weight in SG 99; whereas in M 522, it increased up to 10 May sowing date and significantly (LSD 0.05 = 1.97) decreased in subsequent delay in sowing (Table 1c). Shelling percentage of SG 99 sown on June 10 was significantly higher than that sown on 25 May; whereas in M 522, it significantly and consistently increased up to 25 May sowing (Table 1c). Oil content increased up to 10 May sowing date and decreased in later sowing dates in both cultivars (Table 1c).

Delay in harvesting from 120 to 135 DAS significantly (LSD 0.05 = 1.97) increased the 100 kernel weight (mean of two cultivars) by 9.2%, whereas, further delay in harvesting at 150 DAS did not improve seed size over harvesting at 135 DAS (Table 1d). Increase in shelling out turn in crop harvested at 150 DAS was significant (LSD 0.05 = 1.40) over that harvested at 120 and 135 DAS (Table 1d). Under optimum growth conditions including sowing at recommended time (last week of April to end of May), both of these varieties attain physiological maturity in about 120-125 days with M 522 maturing 2-3 days earlier than SG 99. Delayed harvesting beyond physiological maturity leads to better development of kernels due to transfer of assimilates from plant parts to kernels for longer period and extra time available for development of kernels resulting in higher 100 kernel weight. Adetunji (1991) reported similar results.

Moisture content: Significant variations in seed moisture content were recorded between sowing dates and harvesting dates but not between cultivars. Delay in sowing from 25 April to 25 May resulted in significant (LSD 0.05 = 1.06) and consistent increase in moisture content of harvested seeds (7.6-13.8%). Moisture content significantly (LSD 0.05 = 0.89) decreased with delay in harvesting from 120 (13.9%) to 135 DAS (9.4%) and remained the same at 150 DAS (9.4%). In case of 10 May sowing date, seeds harvested at 135 and 150 DAS contained highest moisture content, whereas, in 25 May sowing, seeds harvested at 120 DAS contained highest moisture content (Table 2). Delay in harvesting to 135 or 150 DAS significantly reduced the moisture content in groundnut sown on 25 May and 10 June compared with 10 May sowing date. Similarly in groundnut harvested at 120 DAS, moisture content in seeds of crop sown on 10 June was significantly lower than 25 May sown crop. Delayed harvesting beyond physiological maturity resulted in decline in moisture content and increase in seed mass. Robertson *et al.* (1978) reported similar reduction in moisture content with delay in maturity. Mehta *et al.* (1993) reported that seeds harvested at 29 Days after Anthesis (DAA) showed the highest moisture percentage while seeds harvested at 45 days after anthesis showed lowest moisture content in chickpea cultivars. Similar results were reported elsewhere (Bharud and Patil, 1990; Kim *et al.*, 1987; Saha, 1987; Dharmalingam and Basu, 1990).

Germination: Maximum germination (92.3%) was recorded in seeds obtained from 10 May sowing date which was at par with 25 May (88.3%) but significantly (LSD 0.05 = 4.4) higher than 25 April (82.2%) and 10 June (85.7%) sowing dates. Germination of seeds harvested at 135 DAS (91.3%) was significantly (LSD 0.05 = 3.2) higher than that harvested at 150 (85.4%) or 120 DAS (84.7%). Seed germination in SG 99 (92%) was significantly (LSD 0.05 = 2.6) higher than M 522 (82.3%). Germination of SG 99 was significantly (LSD 0.05 = 5.2) higher than M 522 in all sowing dates except those sown on 25 May (Table 3a). Similarly, seed germination of SG 99 was significantly

Table 2: Effect of harvesting dates on the moisture content (%) in groundnut sown on different dates

	Moisture content (%)		
	Dates of harvesting		
Dates of sowing	120 DAS	135 DAS	150 DAS
25 April	7.95^{ef}	3.70^{h}	11.15^{d}
10 May	3.40^{h}	16.95^{b}	14.35^{c}
25 May	26.95^{a}	8.72^{e}	5.68^{g}
10 June	12.41^{d}	8.15^{e}	6.30^{fg}

Values with different letters are significantly different at p = 0.05

Table 3a: Effect of sowing dates on the germination (%) of groundnut cultivars

	Germination (%)	
	Cultivars	
Dates of sowing	SG 99	M 522
25 April	85.1^{c}	79.3^{d}
10 May	96.2^{a}	88.4^{bc}
25 May	90.9^{b}	85.8^{bc}
10 June	95.8^{ab}	75.6^{d}

Values with different letters are significantly different at p = 0.05

Table 3b: Effect of harvesting dates on the germination (%) in groundnut cultivars

	Germination (%)	
	Cultivars	
Date of harvesting (days after sowing)	SG 99	M 522
120	88.0[bc]	81.3[d]
135	94.7[a]	87.8[c]
150	93.2[ab]	77.7[d]

Values with different letters are significantly different at p = 0.05

Table 3c: Effect of sowing and harvesting dates on the germination (%) of groundnut cultivars

	Germination (%)		
	Date of harvesting (days after sowing)		
Dates of sowing	120	135	150
25 April	72.0[e]	92.0[ab]	82.7[cd]
10 May	94.3[ab]	90.3[ab]	92.3[ab]
25 May	83.3[cd]	95.6[a]	86.0[c]
10 June	89.0[bc]	87.3[c]	80.6[d]

Values with different letters are significantly different at p = 0.05

higher than M 522 irrespective of harvesting dates (Table 3b). In case of 10 May sowing, highest germination was obtained by harvesting the crop at 120 (94.3%) or 150 DAS (92.3%) whereas, in case of 25 May sowing, crop harvested at 135 DAS resulted in highest (95.6%) seed germination (Table 3c).

Germination of SG 99 was higher than M 522 in all sowing dates. Similarly, seed germination of SG 99 was significantly higher than M 522 irrespective of harvesting dates. Seed germination rates of SG 99 obtained from different sowing dates as well as harvesting dates were faster than M 522 and such differences due to sowing dates were significant. Balasubramanian *et al.* (2011) studied some engineering properties of peanut pod and kernel and observed higher volume, surface area and diameter of M 522 than SG 99. These properties probably led not only to faster but higher percentage germination of the later than the former cultivar. Germination was higher in large size seeds and lower in small size of groundnut (Borate *et al.*, 1993) and in green gram (Bhingarde and Dumbre, 1993). Harvesting the crop earlier resulted in poor seed quality owing to immaturity (Bhingarde and Dumbre, 1993). Similar results were reported in Sunflower (Mahesha *et al.*, 2001a; Adetunji, 1991; Kandil, 1982).

Speed of germination: The resultant seeds of 10 and 25 May sown crop registered significantly (LSD 0.05 = 0.64) higher speed of germination (13.3-13.5) than 25 April (11.5 cm) and 10 June (8.4 cm) sowing dates. Germination speed markedly (LSD 0.05 = 0.69) decreased with each delay in harvest from 120 (12.3) to 150 DAS (11.1). Cultivar SG 99 completed conspicuously (LSD 0.05 = 0.56) faster germination (13.3) than M 522 (10.2). Seed germination rates of SG 99 obtained from different sowing dates as well as harvesting dates were faster than M 522 and such differences due to sowing dates were significant (Table 4a).

Table 4a: Effect of sowing dates on the speed of germination in groundnut cultivars

	Speed of germination	
	Cultivars	
Dates of sowing	SG 99	M 522
25 April	12.9[b]	10.2[d]
10 May	16.2[a]	11.3[cd]
25 May	15.1[a]	11.6[c]
10 June	9.0[d]	7.7[e]

Values with different letters are significantly different at p = 0.05

Table 4b: Effect of sowing and harvesting dates on the speed of germination of groundnut

	Speed of germination		
	Date of harvesting (days after sowing)		
Dates of sowing	120	135	150
25 April	8.6[e]	11.9[c]	14.0[b]
10 May	12.2[c]	15.6[a]	13.5[bc]
25 May	14.2[ab]	15.4[a]	10.4[d]
10 June	14.0[b]	4.6[g]	6.4[f]

Values with different letters are significantly different at p = 0.05

Table 4c: Effect of harvesting dates on the speed of germination in groundnut cultivars sown on different dates

	Speed of germination					
	Date of harvesting (days after sowing)					
	120		135		150	
Dates of sowing	Cv. SG 99	Cv. M 522	Cv. SG 99	Cv. M 522	Cv. SG 99	Cv. M 522
25 April	8.9[d]	8.3[d]	14.9[b]	8.9[d]	14.8[b]	13.3[bc]
10 May	15.6[ab]	8.9[d]	17.4[a]	13.8[bc]	15.7[ab]	11.3[c]
25 May	14.9[b]	13.6[b]	17.1[a]	13.7[bc]	13.4[bc]	7.5[de]
10 June	16.2[ab]	11.9[c]	5.1[e]	4.1[e]	5.6[e]	7.2[de]

Cv: Cultivars, Values with different letters are significantly different at p = 0.05

In early sowing dates, germination was faster when crop was harvested late but in case of late sowing (10 June), seeds harvested earlier (120 DAS) showed faster germination than those harvested at later dates (Table 4b). The seeds of SG 99 obtained from 10/25 May sowing and harvesting at 135 DAS registered significantly (LSD 0.05 = 1.94) highest germination speed (Table 4c). There was rapid decline in seed germination rate in case of crop sown late (10 June) and also harvested late (135 or 150 DAS) in both the cultivars (Table 4c).

Longer vegetative and reproductive phenophases in the earlier sowing date might have resulted in better expression of germination traits. Germination speed markedly decreased with each delay in harvest. Shete *et al.* (1992) reported increase in germination with advancement of harvesting dates.

Seedling length: Length of seedlings was significantly influenced by sowing dates, harvesting dates and cultivars. There was consistent and significant (LSD 0.05 = 0.64) increase in mean seedling length (5.6-9.5 cm) with each fortnightly delay in sowing time. Seeds obtained after harvesting at 135 DAS resulted in significantly (LSD 0.05 = 0.69) higher seedling length (8.8 cm) than that harvested at 150 DAS (7.9 cm) which in turn produced significantly higher length of seedlings compared to those harvested at 120 DAS (6.7 cm). Seedling length of SG 99 (8.9 cm) was significantly (LSD 0.05 = 0.56) higher than that of M 522 (6.6 cm).

Length of seedlings of SG 99 was significantly (LSD 0.05 = 1.12) higher than that of M 522 in all the sowing dates (Table 5a). However, increase in seedling length of SG 99 over M 522 was no-significant in all harvesting dates. The highest seedling length of both cultivars was recorded in seeds harvested at 150 DAS in case of 25 April sown crop, at 120 DAS in 25 May sowing date and 135 DAS in 10 June sowing date (Table 5b). In case of 10 May sowing date, seedling length of M 522 was highest when harvested at 135 DAS and in SG 99, it was the highest when harvested at 150 DAS (Table 5c).

Varieties differ significantly on seedling length (Mahesha *et al.*, 2001b) and harvesting stages and harvesting stage produced higher seedling length from the seeds collected at 35 day after flowering which might have resulted from higher germination percentage and vigorous growth (Sardana and Sharma, 2009).

Fresh and dry weight: Similar to speed of germination, fresh weight of seedlings was significantly (LSD 0.05 = 0.125) higher for the seeds obtained from 25/10 May sowing dates as compared to those obtained from 10 June or 25 April sowing dates; the later two were at par with each other. Similar trend was discerned for differences in dry weight due to sowing dates but such differences

Table 5a: Effect of sowing dates on the seedling length (cm) in groundnut cultivars

	Seedling length (cm)	
	Cultivars	
Dates of sowing	SG 99	M 522
25 April	6.1^{d}	5.0^{d}
10 May	8.5^{bc}	6.9^{c}
25 May	9.2^{b}	7.4^{c}
10 June	11.9^{a}	7.2^{cd}

Values with different letters are significantly different at p = 0.05

Table 5b: Effect of sowing and harvesting dates on seedling length (cm) in groundnut

	Seedling length (cm)		
	Date of harvesting (days after sowing)		
Dates of sowing	120	135	150
25 April	4.4^{d}	3.2^{d}	9.0^{b}
10 May	2.9^{e}	10.3^{b}	9.8^{bc}
25 May	10.4^{ab}	9.9^{b}	4.5^{d}
10 June	8.8^{c}	11.7^{a}	8.0^{c}

Values with different letters are significantly different at p = 0.05

Table 5c: Effect of harvesting dates on the seedling length (cm) in groundnut cultivars sown on different dates

	Seedling length (cm)					
	Date of harvesting (Days after sowing)					
	120		135		150	
Dates of sowing	Cv. SG 99	Cv. M 522	Cv. SG 99	Cv. M 522	Cv. SG 99	Cv. M 522
25 April	4.9^{e}	4.1^{ef}	3.6^{ef}	2.8^{f}	9.9^{c}	8.1^{cd}
10 May	3.1^{ef}	2.8^{f}	11.1^{b}	9.6^{cd}	11.4^{bc}	8.3^{cd}
25 May	11.5^{b}	9.3^{cd}	11.1^{bc}	8.8^{cd}	5.0^{e}	4.1^{ef}
10 June	10.0^{b}	7.7^{d}	13.8^{a}	9.6^{cd}	11.9^{ab}	4.2^{ef}

Cv. Cultivars, Values with different letters are significantly different at p = 0.05

were non significant. The highest fresh (LSD 0.05 = 0.070) and dry (LSD 0.05 = 0.013) weights of seedlings were obtained from the seeds harvesting at 135 DAS (0.845 g and 0.093 g, respectively). Crop harvested on early date (120 DAS) produced seeds that resulted in lowest fresh and dry weight of seedlings. Fresh weight of seedlings of SG 99 was significantly (LSD 0.05 = 0.057) higher than M 522. Cultivars failed to conspicuously interact with sowing dates for fresh and dry weight accumulation and with harvesting dates for fresh weight accumulation. Crop sown on 25 April and harvested 150 DAS resulted in significantly (LSD 0.05 = 0.14) higher fresh weight of seedlings compared to other harvesting dates for the same sowing date (Table 6a), whereas in case of crop sown on 25 May, harvesting at 120-135 DAS resulted in higher seedling fresh weight. In all other sowing dates, crop harvested at 135 DAS resulted in significantly higher seedling fresh weight compared to other harvesting dates. In early sowing dates (25 April and 10 May), seedling dry weight increased with delay in harvesting up to 150 DAS, whereas, it increased up to harvesting date of 135 DAS in 25 May sowing date and harvesting date of 120 DAS in case of 10 June sowing date (Table 6b).

Seedling dry weight of SG 99 harvested at 135 and 150 DAS was higher than M 522 (Table 6b). Seedling dry weight increased with delay in harvesting to 150 DAS in SG 99 and to 135 DAS in M 522 (Table 6c).

All the cultivars attained maximum dry matter accumulation at physiological maturity (Mehta *et al.*,1993) thereafter, dry weight decreased because of restricted supply of nutrients from mother plant to seed due to disruption of vascular connection and utilization in various physiological and metabolic processes (Khatun *et al.*, 2010).

Vigour index: Delay in sowing from 25 April to 10-25 May resulted in marked (LSD 0.05 = 53.4) increase in vigor index I, whereas, further delay in sowing to 10 June resulted in significantly higher seedling vigor index I (847.2) than 25 May sowing (738.2). Seeds harvested at 135 DAS showed significantly (LSD 0.05 = 42.6) higher seedling vigor index I (806.4) than that harvested at 150 DAS (705.6) which in turn recorded significantly higher seedling vigor index I than that harvested 120 DAS (569.3). Seedling vigor index I of SG 99 (835.6) was significantly (LSD 0.05 = 34.8) higher than M 522 (551.9). SG 99 attained significantly (LSD 0.05 = 60.3) higher seedling vigor than M 522 in all sowing as well as harvesting dates (Table 7a). This might be due to higher germination percentage and dry weight. Significantly higher seedling vigor index I (LSD 0.05 = 69.6) was registered by SG 99 sown on 10 June compared to other sowing dates.

Table 6a: Effect of sowing and harvesting dates on the fresh weight (g) of groundnut

	Fresh weight (g)		
	Date of harvesting (days after sowing)		
Dates of sowing	120	135	150
25 April	0.463^{f}	0.366^{f}	1.095^{bc}
10 May	0.332^{f}	1.180^{b}	1.080^{bc}
25 May	0.957^{c}	1.500^{a}	0.558^{ef}
10 June	0.672^{de}	0.856^{cd}	0.725^{d}

Values with different letters are significantly different at p = 0.05

Table 6b: Effect of sowing and harvesting dates on the dry weight (g) of groundnut

	Dry weight (g)		
	Date of harvesting (days after sowing)		
Dates of sowing	120	135	150
25 April	0.057^{c}	0.079^{b}	0.113^{a}
10 May	0.076^{bc}	0.078^{b}	0.103^{ab}
25 May	0.058^{c}	0.129^{a}	0.084^{b}
10 June	0.106^{ab}	0.075^{bc}	0.067^{c}

Values with different letters are significantly different at p = 0.05

Table 6c: Effect of harvesting dates on the dry weight (g) of groundnut cultivars

	Dry weight (g)	
	Cultivars	
Dates of sowing (Days after sowing)	SG 99	M 522
120	0.073^{b}	0.076^{b}
135	0.093^{ab}	0.088^{b}
150	0.108^{a}	0.075^{b}

Values with different letters are significantly different at p = 0.05

Increase in seedling vigor index II though non significant was discerned up to 25 May (10.02) sowing date as compared to earlier sowing dates of 25 April (6.97) and 10 May (8.02). It increased (6.41-9.34) though inconspicuously with each delay in harvesting date. Seedling vigor index II of SG 99 (9.43) was significantly (LSD 0.05 = 2.0) higher than M 522 (6.59).

In all sowing dates, seedling vigor index II was the highest for the crop harvested 150 DAS (Table 7b). Harvesting the seeds before the attainment of physiological maturity recorded lesser viability and vigour potentials due to more number of immature seeds with relatively low degree of embryo development and high moisture content as reported in pea (Matthews, 1973) and later by Khatun *et al.* (2009) in lentil.

Crop sown on 25 May and harvested at 150 DAS resulted in highest vigor index II which was at par with crop sown on 25 April or 10 May and harvested 150 DAS, 25 May sown crop harvested 135 DAS and 10 June sown crop harvested 120 DAS and significantly (LSD 0.05 = 4.9) higher than all other treatments of sowing and harvesting dates (Table 7b). Seedling vigor index II of SG

99 was higher than M 522 in all harvesting dates (Table 7c). Seedling vigor index of M 522 was statistically similar at different harvesting dates. SG 99 harvested at 150 DAS produced seedlings of significantly higher vigor index II (LSD 0.05 = 3.47) than those harvested 120 and 135 DAS and also over M 522 at all harvesting dates. Increased seed vigor index II might be due to maturation of seeds resulting in improvement of germination percentage and seedling length (Gore *et al.*, 1997) further enhanced dry matter of the seedling (Khare and Satpute, 1999).

Correlations: A positive and highly significant correlation (r = 0.916**) was observed between moisture content and vigor index I in SG 99 when harvested at 120 DAS. Moisture content of M 522 was also positively and significantly correlated with vigor index I in all the harvesting dates (r = 0.981** at 120 DAS, r = 0.757* at 135 DAS and r = 0.988 **at 150 DAS).

Table 7a: Effect of harvesting dates on the vigor index I of groundnut cultivars sown on different dates

	Vigor index I					
	Date of harvesting (days after sowing)					
	120		135		150	
Dates of sowing	Cv. SG 99	Cv. M 522	Cv. SG 99	Cv. M 522	Cv. SG 99	Cv. M 522
25 April	379.5^{g}	284.8^{h}	342.5^{h}	251.9^{h}	843.5^{d}	659.1^{f}
10 May	299.7^{h}	258.9^{h}	1039.8^{bc}	835.8^{de}	1224.1^{ab}	719.0^{ef}
25 May	942.5^{c}	798.5^{d}	1056.7^{bc}	836.9^{de}	484.9^{g}	309.4^{h}
10 June	971.0^{c}	619.8^{f}	1320.5^{a}	767.1^{d}	1122.6^{b}	281.8^{h}

Cv: Cultivars, Values with different letters are significantly different at p = 0.05

Table 7b: Effect of sowing and harvesting dates on vigor index II of groundnut

	Vigor index II		
	Date of harvesting (days after sowing)		
Dates of sowing	120	135	150
25 April	4.39^{h}	7.38^{e}	9.14^{d}
10 May	7.18^{e}	6.98^{e}	9.91^{c}
25 May	4.68^{h}	12.38^{b}	13.0^{a}
10 June	9.41^{d}	6.45^{f}	5.34^{g}

Values with different letters are significantly different at p = 0.05

Table 7c: Effect of harvesting dates on vigor index II of groundnut cultivars

	Vigor index II	
	Cultivars	
Dates of sowing (days after sowing)	SG 99	M 522
120	6.57^{d}	6.27^{d}
135	8.87^{b}	7.72^{c}
150	12.9^{a}	5.82^{e}

Values with different letters are significantly different at p = 0.05

There was significant positive correlation (r = 0.899**) between germination per cent and vigor index I in M-522 harvested at 150 DAS. Significant positive correlation between germination % and vigor Index II was also observed in both cultivars irrespective of harvesting date. Correlation of seedling length with vigor index II was positive in M 522 but negative in SG 99 in all harvesting dates. Similar correlations were obtained in *Annona squamosa* by Baburatan *et al.* (1993) and earlier by Ponnuswary *et al.* (1991), *Lens culinaris* (Khatun *et al.*, 2009) and *Cicer arietinum* (Khatun *et al.*, 2010).

Speed of germination in M 522 was also positively correlated with vigor index I and vigor index II at 120 (r = 0.990**) and 150 (r = 0.926**) DAS, whereas significant correlation for this cultivar was noticed with vigour index II at all the harvesting stages. Similar significant positive correlation for SG 99 was observed between speed of germination and vigor index II at all harvesting dates and vigor index I for harvesting done at 120 DAS. Fresh weight of seedling and vigour index I was positively correlated in SG 99 harvested at 120 (r = 0.924**) or 135 (r = 0.816**) DAS and in M 522 harvested at 150 DAS (r = 0.985**). Similar positive correlation of seedling fresh weight with vigor index II was observed for both the cultivars at all harvesting stages except SG 99 harvested at 120 DAS. Dry weight of M 522 was positively correlated with vigor index I at all the 3 harvest stages (r = 0.481 at 120 DAS, r = 0.652* at 135 DAS, r = 0.108 at 150DAS). However, seedling dry weight of SG 99 harvested at 150 DAS was positively correlated with vigor index I. Dry weight showed highly positive and significant correlation with vigor index II in both the cultivars i.e., (r = 0.990** at 120 DAS), (r = 0.999** at 135 DAS) and (r = 0.214 at 150 DAS) for SG 99 and similar trend was recorded for M522 (r = 0.980**; r = 0.976** and r = 0.879**) at 3 stages of harvest. Similar trend has been reported by Reddy and Khan (2001) in lentil. Vigour of the seeds is related to moisture content which affects the germination traits leading to higher pace of germination improving seedling growth in terms of seedling length and dry matter. Gore *et al.* (1997) has attributed higher seed vigor index II probably due to associative effect of germination percentage and seedling length.

CONCLUSION

Seed quality traits were significantly influenced by time of sowing and harvesting. The seeds of crop harvested at 135 DAS produced seeds of better quality in terms of significantly higher germination percentage, seedling length, dry matter accumulation and vigor index than those harvested at 120 or 150 DAS. The present investigation implies the attainment of maximum dry matter (physiological maturity) when harvested at 135 DAS. Bunch type cultivar, SG 99 possessed better quality traits and showed better germination, seedling length, speed of germination, fresh weight, dry weight, vigor index I and vigor Index II than semi-spreading cultivar M 522.

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