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Effect of harvesting stage on seed yield and quality of Okra sown at different dates

Farzana Begum*, **Gohar Ayub**

Department of Horticulture, The University of Agriculture, Peshawar, Pakistan

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Key words: Sowing times, Okra, Harvesting stages, Seed yield, Quality

Abstract

Field experiment was conducted to study the effect of harvesting stages i.e. (mature pod of turning stage, brown undried stage and brown dried stage) on seed yield and quality attributes of okra sown at different dates (March 10, March 30, April 19 and May 9) at Agriculture Research Institute Tarnab Peshawar, during 2016 and 2017. A Randomized Complete Block Design (RCBD) with split plot arrangement having sowing dates as the main plot factor, while harvesting stages as sub plot factor was used. The average of two years results showed that maximum number of seeds pod^{-1} (58.09), seed weight pod^{-1} (3.57g), 1000 seed weight (g), seed yield (1.72t ha^{-1}), germination (79%) and seedling vigor index (2114.16) was observed in plants sown on March 30 as compared to late sown plants on May 9. As for as harvesting stages are concerned, maximum seed weight pod^{-1} (3.57g), 1000 seed weight (61.33g), seed yield (1.67t ha^{-1}), germination (80.73%), and seedling vigor index (2181.73) was recorded when seeds were harvested at brown dried stage. The D x H interaction significantly influenced seed weight pod^{-1}, germination and seedling vigor index.

***Corresponding Author:** Farzana Begum ✉ farzana.rahman86@yahoo.com

Introduction

Okra has prolong period of cultivation due to which it captured a permanent position among vegetable crops in Pakistan, except few winter months okra is cultivated almost throughout the year. It is a generally grown and consumed as fruit vegetable. Farmers usually harvest fruits at edible maturity to sell in the fresh market or dry fruit and partially processed for the market (Tindall, 1983).

In crop production program seed is the basis of agriculture and it is recognized as the main and essential starting points (George, 1985). In the normal cultivation system the use of quality seed, significantly increased the yield of vegetable crops (Rajanna and Andrews, 1970). Seed is the main factor to determine the quantitative and qualitative characteristics of the crop. Hence; increasing seed yield with good quality require extra attention. Successful production of okra seed is conditional to certain agricultural practices (El-Waraky, 2014).

During the seed-filling duration seed quality is susceptible to temperature. Various processes involved in seed filling can differentially affected by high temperature; seed composition can also be affected by heat stress. Functioning of the pollen and seed set is also influenced by environmental stresses prevailing during pollen development, germination, and pollen tube growth (Thuzar *et al*., 2010) and thus reduced the number of seeds and quality. As temperature increases, which reduce seed number, accelerate seed growth rate, reduce the duration of seed filling, and sometimes reduce seed mass (Singh *et al*., 2013). Available reports suggest that sowing date play an important role in growth and pod formation (Randhawe, 1967; Gupta *et. al*., 1982). Due to change in agroclimatic conditions, periodic evaluation of planting dates is of urgent need. Ariyo (1987) reported that 15 okra genotypes were evaluated in 5 different sowing dates and recorded a significant effect for all the parameters during the study (plant height, number of branches plant^{-1}, number of days to flowering, pod weight and pod yield plant^{-1}).

The optimum stage of harvest of okra occupies prime importance for edible as well as for seed purpose and not only in the domestic market, but also for export purpose. For seed production, however, pods are left on the mother plant until they are dry before harvest. The seed crop requires the right stage of maturity followed by proper drying to ensure high germinability after harvest and during storage. This is because seed longevity is known to be influenced by the initial seed quality, which is affected by the production procedure (Bortey and Dzomeku, 2016). To guarantee higher seed yield, vigour and viability, the optimum stage of harvesting is essential. During seed development process, seed maturation might be regarded as a positive process that encompassing additive changes in seed characteristics, which include increase in seed size, dry weight, viability and vigour (Rajanna and Andrews, 1970). Physiological maturity of the seed may be defined as when the seed achieved its maximum dry weight, germination and vigour (Rajanna and Andrews, 1970; Meija, 1985). Seed quality is at its peak at the time of physiological maturity; therefore, being able to identify this stage of development aids a seed grower in optimizing subsequent operations such as harvesting and drying to maximize the germination and vigour of seed produced. Harrington (1960) reported that seeds attain maximum quality at the end of the seed filling period and that thereafter viability and vigour declines. Agrawal (1980) stated that okra seed pod should be harvested when they are dry (*i.e.* about 35 days after anthesis). Delayed harvest may lead to low germination and vigour due to adverse weather conditions in okra (Agrawal, 1980; TeKrony *et al.*, 1980). Similarly, Demir and Ermis (2005) observed that maximum standard germination of okra occurred at 30 days after anthesis. The optimum stage of harvest has a significant influence on the quality of a seed. The seed maturation, however, is closely associated with fruit maturation and complete fruit drying (Ashok *et al.,* 2005). Unfortunately, many farmers lack the knowledge on the manipulation of harvest time for fresh fruit yield; along with this the appropriate maturity time to harvest okra for seed also needs to be known.

These data are required to enable the farmers to obtained the maximum fruit yield and reduce field deterioration when producing seed. However, such studies are limited in okra, an important vegetable crop grown throughout Pakistan.

Keeping in view the consideration, an experiment was conducted with the following objectives:

1. To find out suitable sowing date for achieving high seed yield and quality of okra.
2. To determine the effective stage of harvesting to obtain quality seed with maximum seed germination and vigour.
3. To investigate the interactive effect of sowing dates and stage of harvesting on okra seed yield and quality.

Materials and methods

The experiment entitled "Effect of harvesting stages on seed yield and quality of okra sown at different dates" was carried out at Agriculture Research Institute Tarnab Farm Peshawar during the summer seasons of the years 2016 and 2017. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement having three replications. Date of sowing was kept in main plots, while harvesting stages was allotted to sub plots. The Treatments details were as under.

Factor A. (Main plot factor) Sowing Dates (D)

March	10
March	30
April	19
May	9

Factor B. (Sub plot factor) harvesting stages (H)

H1= Mature pod of turning stage

H2= Brown undried stage

H3= Brown dried stage

Procedure for Data Recording

Number of seeds pod^{-1}

The number of seeds pod^{-1} of the selected plants was recorded and average number of seeds pod^{-1} were calculated.

Seeds weight pod^{-1}(g)

The seeds obtained from selected pods from each plant were weighed separately and the average of seed weight pod^{-1} was calculated and expressed in grams.

1000- Seed weight (g)

The pods from each treatment were harvested and threshed separately. The seeds were dried up to the desired moisture content. 1000-seeds were randomly taken from each treatment and the average weight was recorded and expressed in grams.

Seed yield (t ha^{-1})

The seed yield plot^{-1} was recorded and the seed yield (t ha^{-1}) was computed using the following formula:

$$\text{Seed yield (t ha}^{-1}) = \frac{\text{Seed yield plot}^{-1}\text{ (t) x 10000 m}^2}{\text{Area of plot (m}^2\text{) X 1000}}$$

Germination (%)

Four replications of 100-seeds each were placed on two layers of blotter paper moistened with water equivalent to 2.5 times the substratum weight and germinated on Petri plates at 25^{0}C. Germination (%) counts were taken on the basis of number of normal seedlings after 7 and 12 days. The mean germination (%) was calculated for each treatment (ISTA, 2017).

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds tested}} \times 100$$

Seedling vigor index

The seedlings vigor index was calculated for each treatment by multiplying the germination percentage with seedling length (Abdul-Baki and Anderson, 1973).

Statistical Analysis

The data recorded were analyzed statistically combined over years using analysis of variance techniques appropriate for RCB design with split plot arrangement. Means were compared using LSD test at 0.05 level of probability, when the F values were significant (Steel and Torrie, 1980). The statistical software GenStat release 8.1 (GenStat, 2005) was used for analysis of data.

Results and discussion

Number of seeds pod^{-1}

Data regarding number of seeds pod^{-1} are shown in Table 1. Number of seeds pod^{-1} was significantly influenced by sowing dates and year. The interaction effects for all the treatments remained nonsignificant.

Sowing on March 30 resulted in maximum number of seeds pod^{-1} (58.09) followed by (57.61) in plants sown on April19, while minimum number of seeds pod^{-1} (51.61) were recorded in late sown plants on May 9. Harvesting stage had no significant effect on number of seeds pod^{-1}. However the maximum number of seeds pod^{-1} was obtained, when pods were harvested at dry brown stage. The year effect was found significant. More seeds pod^{-1} (57.12) was recorded during the year 2017 as compared to (54.56) seeds pod^{-1} in 2016.

Lowest number of seed in late sowing may be due to temperature, as during the seed-filling period, seed quality is sensitive to temperature stress. Increasing temperature can causes to hasten seed growth rate, decrease the duration of seed filling which reduce seed number, and reduce seed weight (Singh *et al.*, 2013). Mohamed *et al.* (2016) reported that significant highest number of seed pod^{-1} was recorded following sowing on 1st April, while lowest number of seeds pod^{-1} were observed on 1st May sowing in the first and second seasons, respectively. Bortey and Dzomeku, (2016) also recorded the highest number of seed pod^{-1} from plants, which sown on 1st April. Similar results were also obtained by (Hossain *et al.*, 1999; Moniruzzaman *et al.*, 2007).

It is generally known that the presence of mature pods at the plant has an inhibitory effect on vegetative growth and similarly fruit set (Dhingra, 2009), and this may well extend to seeds inside the same pod. Thus, the reduction in the number of seeds pod^{-1} at later stages of maturation, most prpbabaly due to inter-seed opposition at this time. Bortey and Dzomeku, (2016) recorded the maximum seed pod^{-1} at 40 Days after anthesis. At this stage of fruit maturation, the number of seeds fruit^{-1} recorded was 81.3 significantly more than seeds harvested earlier 71.0 to 74.4 or delayed harvest 73.6. Similarly, Hedau *et al.* (2010) also recorded maximum number of seeds pod^{-1} when the pods were harvested at brown dry stage. A similar result was also recorded by Yadav and Dhankar (2001).

Table 1. Number of seeds pod^{-1} of okra as affected by sowing dates and harvesting stages.

Treatments	Years		Mean
	2016	2017	
Sowing dates (SD)			
March 10	55.01	57.09	56.05 a
March 30	56.53	59.64	58.09 a
April 19	56.09	59.12	57.61 a
May 9	50.60	52.62	51.61 b
$LSD_{(0.05)}$	2.41	4.65	2.33
Harvesting stages			
H1= mature fruit of turning stage	53.51	56.66	55.09
H2= brown undried stage	54.49	57.78	56.14
H3= brown dried stage	55.67	56.92	56.29
$LSD_{(0.05)}$	ns	ns	ns
Year	54.56 b	57.12 a	*
Interactions			
Y x D	ns	Y x H	ns
D x H	ns	YxDxH	ns

Means not followed by the same letters are significantly different.

*, ** show probability level of 5 and 1%, correspondingly

ns means nonsignificant

Seed weight pod^{-1} (g)

Mean values of the data given in Table 2 indicated that seed weight pod^{-1} was significantly affected by sowing dates (D) harvesting stage (H) and year. The interaction between D x H was also significant. Sowing on March 30 had significantly maximum seed weight pod^{-1} (3.57g) followed by (3.51g) in plants sown on April 19 while significantly less seed weight pod^{-1} (2.93g) were noted in late sown plants on May 9. Seed weight pod^{-1} was also significantly influenced by stage of harvesting. Pod harvested at brown dry stage exhibited the maximum seed weight pod^{-1} (3.57g) followed by (3.31g) when pods were harvested at brown undried stage, while the minimum seed weight pod^{-1} (3.01g) were recorded at mature pod of turning stage. The year effect was found significant. More seed weight pod^{-1} (3.39g) was recorded during the year 2017 as compared to (3.21g) seed weight pod^{-1} in 2016. The interaction between D x H revealed that sowing plants on March 30 harvested at brown dry stage exhibited the maximum seed weight pod^{-1} than other D x H interactions (Fig-1).

Seed filling duration may be reduced due to high temperature, which fasten the seed growth rate and may reduce seed weight (Singh *et al.*, 2013).

The seed-filling period is sensitive to temperature. Increasing temperature during growth period can differentially affect the various processes involved in seed filling; it also affects seed composition (Thuzar *et al.*, 2010). Mohamed *et al.* (2016), observed that the heaviest seed weight pod^{-1} was recorded in case of sowing okra plants on 1st April. Significantly, the lowest values of seed weight pod^{-1} were observed on 1st May sowing in the first and second seasons, respectively. Seed weight from different harvesting dates was increased with prolonged time of harvest, since the weight of seeds was increased until 40 days after anthesis and after that it was reduced (Mohamed *et al.*, 2016). Seed maturity is a complex polygenic trait, influenced by genetic and environmental factors that affect morphological, phenological and physiological attributes of the plant (Gwathmey *et al.*, 2016). At first the increase in the dry weight of seed may be due to decrease in moisture content and accumulation of food material with advancement of physiological maturity (Barnwal *et al.,* 2017). According to Demir (1994), physiological seed maturity of okra as expressed by maximum seed dry matter weight and germination could take place ≥35 days after anthesis. However, depending on the cultivar and climatic conditions, the physiological seed maturity could be slightly earlier or later. Similar findings were obtained by (Anitha *et al.,* 2001; Alan and Esar, 2008).

Table 2. Seed weight pod^{-1} (g) of okra as affected by sowing dates and harvesting stages.

Treatments	Years 2016	Years 2017	Mean
Sowing dates (D)			
March 10	3.22	3.17	3.19 b
March 30	3.36	3.77	3.57 a
April 19	3.38	3.63	3.51 a
May 9	2.87	2.99	2.93 c
$LSD_{(0.05)}$	0.25	0.32	0.18
Harvesting stages			
H1= Mature fruit of turning stage	2.88	3.15	3.01 c
H2= Brown undried stage	3.24	3.38	3.31 b
H3= Brown dried stage	3.50	3.65	3.57 a
$LSD_{(0.05)}$	0.27	0.25	0.18
Year	3.21 b	3.39 a	
Interactions			
Y x D	ns	Y x H	ns
D x H	*	YxDxH	ns

Means not followed by the same letters are significantly different.
*, ** show probability level of 5 and 1%, correspondingly
ns means nonsignificant

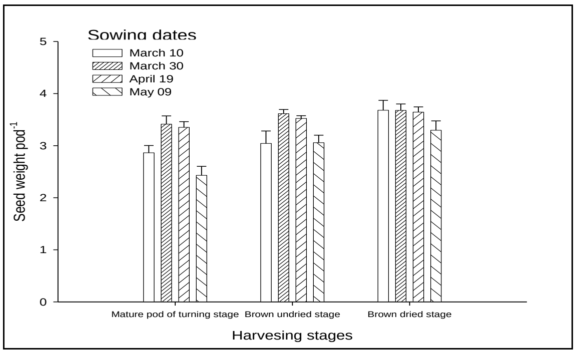

Fig. 1. Seed weight pod^{-1} of okra as influenced by sowing dates and harvesting stages.

1000 seed weight (g)

Mean values of the data given in Table 3 indicated that 1000 seed weight was significantly affected by sowing dates (D) harvesting stage (H) and year. The interaction effect for all the treatments were nonsignificant. Sowing on March 30 had significantly maximum 1000 seed weight (62.57g) followed by (62.49g) in plants sown on April 19, while minimum 1000 seed weight (55.17g) was produced in late sown plants on May 9. 1000 seed weight was also significantly influenced by stage of harvesting. Pod harvested at brown dry stage exhibited the maximum 1000 seed weight (61.33g) followed by (60.57g) when pods were harvest at brown undried stage while the minimum 1000 seed weight (58.34g) were recorded at mature pod of turning stage. The year effect was found significant. More 1000 seed weight (60.76g) was recorded during the year 2017 as compared to (59.39g) 1000 seed weight in 2016.

Direct effects of high temperature on reproduction, particularly pollen formation and function can reduced the seed number and seed weight. Because warming speedup the reproductive development, the seeds that do develop are often small (Thuzar *et al.*, 2010). For higher seed yield, okra requires favorable climatic conditions. The optimum date of sowing determined the plant growth and seed yield (Ashok, 2002). The present results are in similarity with the results of (Mohamed *et al.*, 2016) who stated that maximum 100 seeds weight was obtained from plants sown on 1st April, while minimum 100 seed weight was obtained from plants sown on 1st May, in both seasons. The results are in accordance with those found by Muhammad *et al.* (2015).

The 1000 seed weight is strongly affected by genetic and environmental factors and its amount is affected by the condition of maturity period, these conditions may leads to 20-30% changes in 1000 seed weight and the higher potential of 1000 seed weight it might due to the initial capacity and more amount of nutrients available for germination. Ibrahim and Oladiran (2011) observed that 100 seed weight was increased between 14 and 35 days after anthesis while Mistry and Hossain (2008) reported that 100 seed weight were statistically significant at 30 days after flowering. The higher 100 seed weight (4.0g) reached its maximum at 40 days after anthesis and thereafter decreased slightly (Bortey and Dzomeku, 2016). Similar results were also obtained by Hedau *et al.* (2010), who stated that 1000 seed weight was highest when the pods were harvested at brown dry stage.

Table 3. 1000 seeds weight (g) of okra as affected by sowing dates and harvesting stages.

Treatments	Years		Mean
	2016	2017	
Sowing dates (D)			
March 10	59.67	60.49	60.08 b
March 30	62.07	63.08	62.57 a
April 19	62.20	62.78	62.49 a
May 9	53.64	56.70	55.17 c
$LSD_{(0.05)}$	1.98	2.05	1.27
Harvesting stages (H)			
H1= Mature fruit of turning stage	57.48	59.21	58.34 b
H2= Brown undried stage	59.81	61.32	60.57 a
H3= Brown dried stage	60.90	61.75	61.33 a
$LSD_{(0.05)}$	1.39	1.59	1.01
Year	59.39 b	60.76 a	
Interactions			
Y x D	ns	Y x H	ns
D x H	ns	Y x D x H	ns

Means not followed by the same letters are significantly different.

*,**show probability level of 5 and 1%, correspondingly.

ns means nonsignificant

Seed yield (t ha^{-1})

The seed yield as affected by sowing dates, harvesting stage and year is presented in Table 4. Significant difference was found among the sowing dates, harvesting stage and year. None of the interactions were significant regarding seed yield. Sowing seeds on March 30 produced the highest seed yield of (1.72t ha^{-1}) followed by (1.64t ha^{-1}) in plants sown on April 19, whereas late sown plants on May 9 produced least (1.46t ha^{-1}) seed yield. Pod harvested at brown dry stage exhibited the maximum seed yield (1.67t ha^{-1}) followed by (1.60t ha^{-1}) when pods were harvest at brown undried stage, while the minimum seed yield (1.55t ha^{-1}) were recorded at mature pod of turning stage. Data regarding the year revealed that seed yield was maximum (1.63t ha^{-1}) during 2017 as compared to (1.59t ha^{-1}) in 2016.

High quality of seeds is reflected directly on the yield of the crop, providing uniformity of the population, high vigor of seedlings and plants, absence of pathogens transmitted by seeds and consequently, greater production (De Bittencourt *et al.*, 2012). To have optimal yield, determination of proper planting date is tought of a very important effort. Both quantitative and qualitative traits of crops depend upon on sowing on the proper date and growing season (Farrag, 1995). Smililar results were obtained by Incalcaterra, (2000) who recorded good vegetative growth and high fruit setting in April sowing as compared to March sowings. Vigourus vegetative growth and pod yield resulted in high seed yield. Sharif, (2002) stated that March sowing recorded the maximum seed yield in comparison with sowing in May. The results are in correlation with the results of Shahid *et al.* (2015), who stated that the higher seed yield (1601.92kg ha^{-1}) was recorded from okra cultivars sown on 30th March 2014, while the least seed yield (1402.36kg ha^{-1}) was obtained from cultivars sown on 14th April.

In okra, seed quality is found to be affected by fruit position, seed maturity and growing season (Prabhakar *et al.,* 1985). According to Nonnecke (1989), okra must be harvested at the most appropriate stage for maximum yield, quality and acceptability. Hedau *et al.* (2010) observed the highest seed yield from fruits harvested at undried brown and dry brown stages of maturity. This assertion could complement the observations made by Bewly and Black (1994), who reported that fruits harvested between 25-30 DAA could record higher seed yields in the range of 70-80 seeds pod^{-1}. Bortey and Dzomeku, (2016) recommended that for production of higher seed yield and quality of okra, the optimum stage of harvesting should be ≥40 days after anthesis.

Table 4. Seed yield (t ha^{-1}) of okra as affected by sowing dates and harvesting stages.

Treatments	Years		Mean
	2016	2017	
Sowing dates (D)			
March 10	1.58	1.63	1.61 b
March 30	1.73	1.71	1.72 a
April 19	1.60	1.68	1.64 b
May 9	1.44	1.48	1.46 c
$LSD_{(0.05)}$	0.08	0.09	0.05
Harvesting stages (H)			
H1= Mature fruit of turning stage	1.52	1.57	1.55 c
H2= Brown undried stage	1.58	1.62	1.60 b
H3= Brown dried stage	1.66	1.69	1.67 a
$LSD_{(0.05)}$	0.08	0.07	0.05
Year	1.59 b	1.63 a	
Interactions			
Y X D	ns	Y x H	ns
D x H	ns	Y x D x H	ns

Means not followed by the same letters are significantly different.

*,**show probability level of 5 and 1%, correspondingly.

ns means nonsignificant

Germination (%)

Mean values of the data given in Table 5 indicated that germination (%) was significantly affected by sowing dates (D) and harvesting stage (H). The D x H interaction remained significant, while rest of the interactions were not significant. Seed harvested from plants sown on March 30 had significantly highest seed germination (79.00%) followed by in seeds harvested from plants sown on April 19 (75.80%) and the least germination (64.82%) were recorded in seed harvested from late sown plants on May 9. The germination (%) of the seed was also significantly affected by stage of harvesting. Pod harvested at brown dry stage resulted in the highest seed germination (80.73%), followed by brown undried stage (77.63%) and the least germination (61.75%) was recorded at mature pod of turning stage. The D x H, indicated that sowing seed on March 30 and harvested at brown dry stage exhibited the highest seed germination than other D x H interactions (Fig-2).

The lowest germination in delay sowing may be due to high temperature stress during seed filling duration, which can decrease germination by reducing the ability of the plant to provide the assimilates essential to synthesize the storage compounds necessary for the germination process (Hampton *et al.*, 2013), and the ability of seed to germinate is lost, if the seeds endure physiological damage (Powell, 2006), seed vigour is also reduced significantly due to high temperature stress both before and after physiological maturity (Hampton *et al.*, 2013). Mohamed *et al.* (2016) noted that seed germination of okra was significantly influenced by sowing dates in both seasons. Maximum germination (71.1 and 73.1%) was recorded from seeds of okra plants sown on 1st April, while, significantly minimum germination (53.1 and 57.3%) was recorded when seeds were sown on 1st May in the first and second seasons, respectively. Similar results found by Muhammad *et al.* (2001), who revealed that the maximum germination was observed when seeds sown on either April 15 or May 5.

Premature harvesting or harvesting at the stage of senescence can reduced seed germination (Setubal *et al.*, 1994; Passam *et al.*, 1998). The low germination of early harvested seeds may be due to the high amount of immature seeds in these sets of seeds, whereas due to proper and proportionate development of embryo and endosperm seeds become viable and vigorous and hence more germination occurred. Godon *et al.* (1979) also reported that immature seeds are known to germinate poorly. The maximum germination of okra seed was recorded when seeds were harvested 27 to 30 days after anthesis (Purewal and Randhawa, 1947; Chauhan and Bhandari, 1971; El-Hag, 1979). The result was also consistent with that of Oladiran and Agunbiade (2000) in okra. Mugnisjah and Nakamura (1984) also reported similar trend in soybean that early harvest may result in poor germination and vigour.

Devadas *et al.* (1998) reported that the developing seeds achieved germinable maturity at 21 days after anthesis and highest germination was recorded at 30 to 36 days after anthesis. This was also supported with findings of Berchie *et al.* (2004) and El Balla *et al.* (2011). Manohar (1969) reported that maximum germination (97%) of okra seeds were recorded when harvested at 21 days from flowering. Verma *et al.* (2004) also observed that among the stages of harvest, from the brown undried stage and brown dried stage exhibited maximum seed germination during both the year.

Table 5. Germination (%) as affected by sowing dates and harvesting stages.

Treatments	Years		Mean
	2016	2017	
Sowing dates (D)			
March 10	73.69	74.00	73.84 c
March 30	80.11	77.89	79.00 a
April 19	75.71	75.89	75.80 b
May 9	64.98	64.67	64.82 d
$LSD_{(0.05)}$	2.00	1.54	1.12
Harvesting stages (H)			
H1= Mature fruit of turning stage	62.33	61.17	61.75 c
H2= Brown undried stage	78.00	77.25	77.63 b
H3= Brown dried stage	80.54	80.92	80.73 a
$LSD_{(0.05)}$	1.79	1.43	1.10
Year	73.62	73.11	
Interactions			
Y X D	ns	Y x H	ns
D x H	**	Y x D x H	ns

Means not followed by the same letters are significantly different.

*,**show probability level of 5 and 1%, correspondingly.

ns means nonsignificant

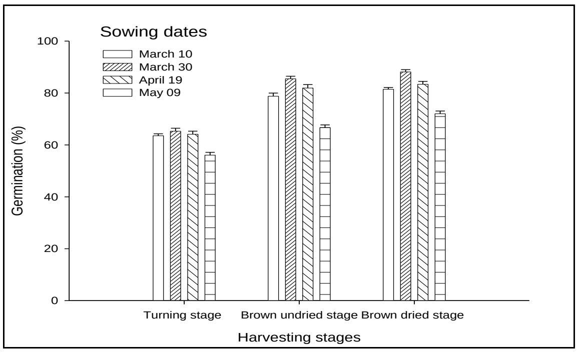

Fig. 2. Germination (%) of okra seed as influenced by sowing dates and harvesting stages.

Seedling Vigour Index

Mean values of the data given in Table 6 indicated that seedling vigor index was significantly affected by sowing dates (D) harvesting stages (H) and Storage duration (S). The D x H interaction remained significant, while rest of the interactions were not significant. Seed obtained from plants sown on March 30 had significantly highest seedling vigor index (2114.16) followed by 19 April sowing (1995.34) and the lowest seedling vigor index (1535.01) were recorded in seed harvested from late sown plants on May 9. The seedling vigor index was also significantly affected by stage of harvesting. Pod harvested at brown dry stage resulted in the highest seed vigor index (2181.73), followed by brown undried stage (1981.47) and the lowest seedling vigor index (1460.91) were recorded at mature pod of turning stage. The D x H, indicated that sowing on March 30 and harvested at brown dry stage exhibited the highest seedling vigor index than other D x H interactions (Fig-3).

Seed vigor comprises those attributes that determine the potential for rapid, uniform development of normal seedlings under different field conditions (Kandpal *et al.*, 2016). Perry (1972) stated that seed vigour is not equivalent of seed germinability. Vigour is defined by the ISTA as the sum total of these properties of the seed, which determine the potential level of activity and performance of a dormant seed. To determine the physiological maturity of seeds germination percentage and seedling vigour are considered an important parameters (Singh and Sindhu, 1985). Physiological deterioration of seeds is induce or increases by high temperature (Powell, 2006), and limited evidence suggests that at critical stages of seed development only short periods of high temperature stress are required to decrease seed vigour (Hampton *et al.*, 2013). Similar results were also obtained by Rahman *et al.* (2013) in soybean, who recorded decreased germination and vigour index of seed with delayed sowing. Chattopadhyay *et al.* (2011) reported that February 16 and March 01 sowing recorded higher germination and seed vigour index as compared to May sowing.

The results are in close conformity with previous reseachers (Huda and Samiruddin, 1987; Moniruzzamam *et al.*, 2007), who stated that quality seeds of okra can be produced in Mid-February to Mid-March.

Early harvesting before physiological maturity can decreases seed yield and quality especially due to undeveloped and immature seeds. Harvesting time of several crops depends on its maturity time and on physiological maturity. Seed quality such as germination, vigor, viability and also storability is affected by harvesting stage (Khatun *et al.,* 2009). To ensure seed quality in terms of germinability and vigour, seeds should be harvested at proper time. Harvesting seeds at physiological maturity have well developed, matured and possess maximum viability and vigour. Sajjan and Jamadar (2003) also recorded higher seed vigour index when the pods of okra were harvested at 40 days after flowering, which was statistically significant over all the harvesting stages. Mugnisjah and Nakamura (1984) also reported similar trend in soybean, that early harvesting of seeds may result in poor germination and vigor index. Verma *et al.* (2004) reported that among the stages of pod harvest, the maximum seed vigour index was recorded in brown dried stage, while it was minimum in mature pods of turning stage, in both the years.

Table 6. Seedling vigor index as affected by sowing dates and harvesting stages.

Treatments	Years 2016	Years 2017	Mean
Sowing dates (D)			
March 10	1882.11	1826.53	1854.32 c
March 30	2154.22	2074.09	2114.16 a
April 19	1981.00	2009.68	1995.34 b
May 9	1566.00	1504.01	1535.01d
LSD(0.05)	94.79	102.55	62.17
Harvesting stages (H)			
H1= Mature fruit of turning stage	1500.25	1421.58	1460.91c
H2= Brown undried stage	1998.83	1964.11	1981.47 b
H3= Brown dried stage	2188.42	2175.05	2181.73 a
LSD(0.05)	104.33	85.34	64.76
Year	1895.83	1853.58	
Interactions			
Y X D	Ns	Y x H	ns
D x H	**	Y x D x H	ns

Means not followed by the same letters are significantly different.

*, ** show probability level of 5 and 1%, correspondingly ns means nonsignificant

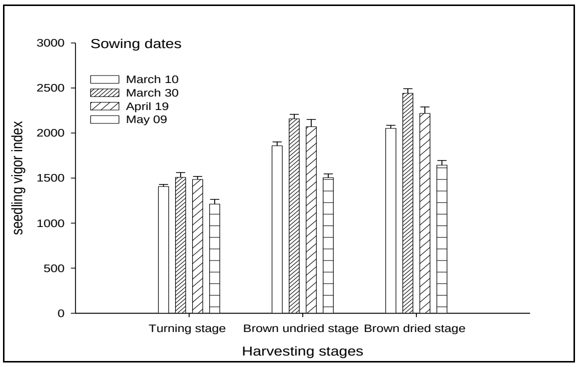

Fig. 3. Seedling vigor index of okra seed as influenced by different sowing dates and harvesting stages.

Summary conclusion and recommendations

Summary

The seed crop requires the right stage of maturity followed by proper drying to ensure high germinability after harvest and storage. This is because seed longevity is known to be influenced by the initial seed quality, which is affected by the production procedure. Therefore, the study was carried out to explore the effect of harvesting stages on seed yield and quality of okra sown at different dates. The study was conducted at Agriculture Research Institute Tarnab Peshawar, during the year 2016 and repeated in 2017. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement replicated three times. Okra seed were sown on different dates i.e. March 10, 30, April 19 and May 9 and harvested at three different stages (Mature pod of turning stage, brown undried and brown dried stage) for seed production.

Results of the study revealed that seeds harvested from plants sown on March 30 recorded the maximum number of seed pod^{-1} (58.09) seed weight pod^{-1} (3.57g), 1000 seed weight (62.57g) and seed yield (1.72t ha^{-1}), germination (79.00%) and seedling vigor index (2114.16) than the seeds harvested from late sown plants on May 9. Harvesting stages also significantly affected seed yield and quality of okra. Maximum seed weight pod^{-1} (3.57g), 1000 seed weight (61.33g) and seed yield (1.67t ha^{-1}), germination (80.73%) and seedling vigor index

(2181.73) was recorded when seeds were harvested at brown dried stage.

Interaction between D x H revealed that sowing on march 30 with harvesting pod at brown dried stage resulted in maximum seed weight per pod (g), germination (%) and seedling vigor index Year used a source of variation indicated the superior seed yield and quality during 2017 as compared to 2016 which may be due to favorable climatic conditions in 2017.

Conclusions

On the basis of these findings, it could be inferred that

- Late sowing (9th of May) had significant negative effect seed yield (number of seeds pod^{-1}, seed weight pod^{-1}, 1000 seed weight, seed yield) and quality (germination and seedling vigor index).
- High okra seed yield and quality was obtained at sowing (30th March).
- For seed purpose, the optimum stage of harvesting is based on the stage that gives optimum germination percentage along with optimum yield. Based on these findings, pods harvested at undried brown and dry brown stages possess maximum number of seeds pod^{-1}, seed weight pod^{-1}, 1000 seed weight, seed yield, germination percentage and seedling vigor index.

Recommendations

1. The last week of March is recommended for the local growers of Peshawar to produce higher seed yield and quality of okra crop.
2. For seed purpose the mature pods should be picked at dry brown stage for obtaining good quality seed of okra.

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