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Effect of stages of harvesting and threshing methods on seed quality of soybean [*Glycine max* (L.) Merrill] cv. DSb-21

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Abstract
A research study was conducted to determine the most appropriate stage of harvesting and the best threshing method with minimal impact on seed quality characteristics of soybean seeds. The field experiment was conducted in 'H' Block of seed unit in two factorial randomized complete block design (RCBD) in three replications with the different treatments of harvesting soybean pods at 90 days after sowing (DAS), 100 DAS and 110 DAS and the threshing of seed was done by three methods viz., Stick beating (T_1), Tractor trampling (T_2) and Mechanical thresher (T_3) and the seed quality was analyzed in the Post Graduate laboratory of the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad. The study revealed that among harvesting stages, soybean harvested at 90 DAS recorded highest germination (90.71%) and moisture (13.19%), vigour (2768) and lower mechanical damage (11.16%), EC (0.34 dS/m) as compared to other harvesting stages. Delaying harvesting viz., 100 DAS and 110 DAS resulted in increased seed leachates and mechanical damage. Among threshing methods, beating with sticks recorded less mechanical damage (10.16%) and maximum germination (92.70%), vigour (2850) and tractor trampling resulted in higher mechanical damage (15.71%), EC (0.38 dS/m) and minimum germination (85.65%) and vigour (2508). Results obtained indicated that for good seed quality, soybean pods should be harvested at 90 DAS and threshed by beating with sticks.

Keywords: Stages of harvesting, threshing methods, seed quality of soybean

1. Introduction
Soybean [*Glycine max* (L.) Merrill] is an important oil seed crop and an annual legume. It is a most delicate crop, looses its seed viability and vigour during harvest and post-harvest operation subsequently resulting in low germination. Greven *et al.* (2004) [6] reported that stages of harvest are an important factor since seed immaturity reduces seed quality. Quality seed production is an important pre-requisite for the agricultural production. Optimum stage of harvesting is a crucial factor as it directly impacts on seed moisture and mechanical damage. Soon after harvest, soybean seed is subjected to several post-harvest operations like threshing, drying, grading, transportation and other handling operations.

Threshing is an important post-harvest operation. In India threshing of soybean seed is generally done by hand beating of pods with sticks and trampling the pods under the feet of bullocks or using a stone roller yoked to a pair of bullocks or other common practice is the use of tractors and mechanical thresher. These methods involve the rubbing action for separating the seed and threshing. Soybean seed is susceptible to mechanical damage during the threshing operations because of its very thin seed coat and low lignin content that leads to little protection to the fragile radical which lies in a vulnerable position directly beneath the seed coat Beating with sticks seems to be an alternative to avoid the damage to the seeds. But, it becomes impractical, as it is time consuming and requires more labour and huge cost.

The maintenance of seed quality after harvest to next sowing is a major problem in soybean seed because the seed is more vulnerable to mechanical damage from harvesting to next sowing season, so soybean seed is regarded as a poor storer and it loses its viability and vigour at a faster rate due to loss of membrane permeability of seeds.

Keeping this in view the present experiment on seed quality in soybean [*Glycine max* (L.) Merrill] cv. DSb-21 as influenced by stage of harvesting and threshing methods on seed quality was carried out.

2. Material and methods

The field experiment was conducted in 'H' Block of seed unit in two factorial randomized complete block design (RCBD) in three replications with the different treatments of harvesting soybean pods at 90 DAS (H_1), 100 DAS (H_2) and 110 DAS (H_3) and the threshing of seed was done by three methods viz., Stick beating (T_1), Tractor trampling (T_2) and Mechanical thresher (T_3) and the quality analysis was carried out in the Post Graduate laboratory of the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad.

2.1 Seed mechanical damage (%)

One hundred seeds were drawn from each treatment in three replications. These seeds were soaked in 20 per cent solution of ferric chloride ($FeCl_2$). After five minutes of soaking, the seeds were removed and individual seeds were observed for their mechanical damage. The seeds with cracks or streaks stained dark green and swelled seeds were separated and recorded as mechanically damaged seeds and expressed in percentage based on number of stained seeds (Mc. Donald, 1999).

2.2 Germination percentage

The standard germination test was conducted as per the ISTA Rules (Anon, 2011) [3] by adopting the rolled paper towel between paper method in four replications of randomly drawn 100 seeds. Rolled paper towel was kept at 25 + 1 ºC and 95 + 1 per cent relative humidity (RH) in the seed germinator. On eighth day of germination test (final count), number of normal seedlings were counted and were expressed as germination percentage.

2.3 Seedling vigour index

The seedling vigour index was calculated as per the formula given by Abdul-Baki and Anderson (1973) [1] and expressed in pure number.

Vigour index = Germination (%) × [Shoot length (cm) + Root length (cm)]

2.4 Electrical conductivity of seed leachate

Electrical conductivity of seed leachate was calculated by taking five gram of randomly drawn seed material in four replications from each treatment and weighed up to two decimal points. The seeds were surface sterilized with acetone for half a minute and washed thoroughly for several times with distilled water and then soaked in beaker with 25 ml distilled water in it. The beakers were kept in incubator at constant temperature of 25 + 1 ºC for 24 h along with blank. The electrical conductivity of seeds leachate was measured in the digital electrical conductivity meter, the actual EC due to the electrolyte (leachate) was measured and expressed in dS m^{-1}.

2.5 Seed moisture content (%)

Moisture content of seeds was determined by adopting the Low Constant Temperature Oven method (103º + 10 ºC for 17 + 1 hr) as per the ISTA Rules (Anon, 2011) [3] and was expressed as moisture content in percentage on wet basis by using the following formula.

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,

W_1: Weight of the empty aluminium dish with lid (g)

W_2: Weight of empty aluminium dish + seed sample before drying (g)

W_3: Weight of the empty aluminium dish + seed sample after drying (g)

2.6 Statistical analysis

The data collected from the experiment was analyzed statistically and subjected to the analysis of variance by adopting the appropriate methods as outlined by Sundar rajan *et al.* (1972) [11]. Critical differences were calculated at one per cent level. In the tables, the critical difference values were given for those observations which were significant at one per cent.

3. Results and Discussion

3.1 Germination per cent: Stages of harvesting showed significant difference for germination percentage. Lowest germination percentage (87.33) of seed was observed in H_3 (110 DAS) and highest germination percentage (90.71) of seed observed in H_1 (90 DAS). Threshing methods also showed significant difference. Highest germination percentage (92.70) was recorded in T_1 (Beating with sticks) and lowest seed germination (85.65) was observed in T_2 (Tractor trampling). The interaction effect between stages of harvesting and threshing methods on seed germination percentage of soybean was found significant. Seeds harvested at H_1 (90 DAS), threshed with beating with sticks method (H_1T_1) recorded significantly higher seed germination (94.23) and lowest (83.00%) was in H_3T_2 (110DAS and tractor trampling) than rest of the treatment combinations.

3.2 Seedling vigour index: Stages of harvesting showed significant difference. Lowest seedling vigour index (2572) of seed was observed in H_3 (100 DAS) and highest seedling vigour index (2768) of seed was observed in H_1 (90 DAS). Threshing methods showed significant difference. Highest Seedling vigour index (2850) was recorded in T_1 (Beating with sticks) and lowest (2508) was observed in T_2 (Tractor trampling). The interaction effect between stages of harvesting and threshing methods on seedling vigour index of soybean was found significant. Stage of harvesting (90 DAS) threshed with sticks beating method (H_1T_1) recorded significantly higher seedling vigour index (3021) and lowest (2370) was in H_3T_2 (110DAS and tractor trampling) than rest of the treatment combinations.

3.3 Electrical conductivity (dS m^{-1}): Stages of harvesting showed significant difference. Lowest EC (0.34 dS m^{-1}) of seeds was observed in H_1 (90 DAS) and highest EC (0.36 dS m^{-1}) of seeds observed in H_3 (110 DAS). Threshing methods and their interaction showed non-significant differences for electrical conductivity of seeds. Numerically lowest EC (0.32 dS m^{-1}) of seeds was observed T_1 and highest (0.38 dS m^{-1}) was in T_2. Among interaction, H_3T_2 resulted in highest EC (0.39 dS m^{-1}) of seeds as compared to other treatment combinations.

3.4 Moisture content (%): Stages of harvesting showed significant difference. Highest moisture content of seed (13.19%) was observed in H_1 (90 DAS) and lowest (10.39%) was observed in H_3 (110 DAS). Threshing methods has shown non-significant differences for moisture content of seed (%). Numerically highest moisture content of seeds (11.67%) was

observed in T_1 and lowest (11.52%) was in T_2. Among interaction H_3T_2 had lowest seed moisture content (10.33%) as compared to other treatment combinations.

3.5 Mechanical damage (%): The stages of harvesting differed significantly for mechanical damage (%). Harvesting at 110 DAS (H_3) recorded significantly higher mechanical damage (14.49%) as compared to 100 DAS (H_2) (13.12%) and 90 DAS (H_1) (11.16%). The threshing methods also differed significantly for mechanical damage (%). Tractor trampling (T_2) recorded significantly higher mechanical damage (15.71%) compared to mechanical thresher (T_3) (12.90%) and beating with sticks (T_1) (10.16%). The interaction effect between stages of harvesting and threshing methods on mechanical damage (%) of soybean was found significant. Harvesting at H_3 (110 DAS) and threshing with tractor trampling (T_2) method recorded significantly higher mechanical damage (17.21%) than rest of treatment combinations.

As the harvesting stage proceeded from H_1 to H_3 (90 DAS to 110 DAS), seed moisture content reduced. The extent of mechanical damage directly related with the seed moisture content. Harvesting at 110 DAS (H_3) recorded higher mechanical damage, compared to 100 DAS (H_2), 90 DAS (H_1). It was due to reduction in the seed moisture content from H_1 to H_3 stage of harvesting. Very dry seeds are more susceptible to mechanical damage and related injuries and may lead to physical damage or fracturing of essential seed parts, make the seed vulnerable to fungal attack (Justice and Bass, 1979). Among the threshing methods, tractor trampling (T_2) recorded significantly higher mechanical damage (15.71%) compared to mechanical thresher (T_3) (12.90%) and beating with sticks (T_1) (10.16%). Due to its thin seed coat, soybean seeds were readily susceptible to the mechanical damages while threshing and also as more pressure was exerted by tractor wheels on seeds. Results are in conformity with Ujjinaiah and Shreedhara (1998) [12] and El-Abady *et al*. (2012) [4] in soybean.

Lowest germination percentage (87.33) of seed was observed in H_3 (110 DAS) and highest germination percentage (90.71) of seed was observed in H_1 (90 DAS). As the harvesting period delayed, the germination percentage was reduced because the deterioration processes begins ever since seed development starts. During seed development, anabolic processes predominate and bring about gradual decrease in dry matter including development of embryo and food reserve. Results are in accordance with Gaikwad and Bharud (2017) [5] in soybean and Mahesha *et al*. (2001) [9] in sunflower.

Among threshing methods, highest germination percentage (92.70) was recorded in T_1 (Beating with sticks) and lowest seed germination (85.65%) was observed in T_2 (Tractor trampling). It was due to impact of mechanical damage on seed, as seeds threshed by tractor trampling (T_2) suffered more physical injury as compared to other methods. Results are in accordance with the findings of Prakobbon (1982) [10], Addo *et al*. (2004) [2] and Kausal *et al*. (2006) [8], Vieira *et al*. (2006) [13] in soybean reported that seed threshed by hand have a higher germination percentage and lower percentage of abnormal seedlings than beaten and machine threshed seeds.

Harvesting at H_3 stage (110DAS) and Tractor trampling (T_2) recorded highest electrical conductivity than the other methods. It was due to increased membrane permeability and the cause of membrane degradation likely due to lipid peroxidation which is detrimental at the intracellular level and also due to the mechanical damage.

The study revealed that for good seed quality, soybean pods should be harvested at 90 DAS and threshed by beating with sticks.

Table 1: Effect of stages of harvesting and threshing methods on seed quality of soybean *Glycine max* (L.) Merrill

Treatments	Germination (%)	Seedling Vigour index	EC (dS m^{-1})	Moisture content (%)	Mechanical damage (%)
H_1	90.71	2768	0.34	13.19	11.16
H_2	89.42	2714	0.35	11.20	13.12
H_3	87.33	2572	0.36	10.39	14.49
Mean	89.15	2685	0.35	11.59	12.92
S. Em. ±	0.18	11.69	0.01	0.07	0.11
C.D. (P=0.01)	0.73	47.61	0.03	0.27	0.45
T_1	92.70	2850	0.32	11.67	10.16
T_2	85.65	2508	0.38	11.52	15.71
T_3	89.11	2700	0.35	11.59	12.90
Mean	89.15	2686	0.35	11.59	12.92
S. Em. ±	0.18	11.69	0.01	0.07	0.11
C.D. (P=0.01)	0.73	47.61	NS	NS	0.45
H_1T_1	94.23	3021	0.31	13.27	8.23
H_1T_2	87.55	2593	0.37	13.11	14.12
H_1T_3	90.34	2745	0.35	13.18	11.14
H_2T_1	92.87	2855	0.32	11.30	10.04
H_2T_2	86.40	2529	0.38	11.11	15.81
H_2T_3	89.00	2708	0.35	11.20	13.53
H_3T_1	91.00	2860	0.34	10.45	12.23
H_3T_2	83.00	2370	0.39	10.33	17.21
H_3T_3	88.00	2647	0.36	10.40	14.05
Mean	89.15	2703	0.35	11.59	12.92
S. Em. ±	0.31	20.26	0.01	0.11	0.19
C.D. (P=0.01)	1.26	82.46	NS	NS	0.78

4. Conclusion

The investigation on effect of stages of harvesting and threshing methods on seed quality of soybean [*Glycine max* (L.) Merrill] cv. DSb-21, revealed that for good seed quality, soybean pods should be harvested at 90 days after sowing and among the threshing method beating with sticks proved to

batter as the seed quality parameters such as germination, vigour were maximum, seed mechanical damage and EC was lowest.

5. References

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