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# Seed Rate and Sowing Method induced Variation in Phenology, Seed Yield and Seed Quality of Soybean [*Glycine max* (L.) Merill]

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**ABSTRACT: Soybean is highly sensitive to soil moisture stress. Due to climate change, erratic weather events hamper soybean production and productivity by disturbing the plant's phenology, metabolism, and other physiological processes. Different seed rates, tillage, and drainage methods may have a high impact on the phenology and productivity of Soybean. Under flatbed sowing, the plant root will suffer from water logging due to high rainfall. In M.P., farmers apply high seed rates and narrow spacing of plants and rows to avoid less plant populations' risk. Under prevailing high-density planting, at the seed rate of 70 kg ha$^{-1}$ and flatbed sowing method, plant growth is restricted due to limitation of radiation and nutrients. Hence, the seed rate and sowing method need revision in an era of climate change. Therefore, we hypothesized that adopting a lower seed rate under ridges and furrow sowing would improve phenology, seed yield, and seed quality over the prevailing seed rate of 70 kg ha$^{-1}$ and the flatbed sowing method. Studies revealed that phenological development was significantly affected by seed rate during the entire span of Soybean. The minimal increment of 2.05 %, 2.53% on days to flower initiation, days to 50% flowering was observed in 50 kg ha$^{-1}$. For seed quality attributes, 60 kg ha$^{-1}$ was found to be superior in the enhancement of germination percentage (1.88%) and seedling length (2.36%) over control (70 kg ha$^{-1}$). Ridges and furrows sowing method exhibited superiority for seed quality attributes in terms of enhancement in germination percentage (4.56%), seedling length (2.20%), vigour index I (1.46%), and vigour index II (3.0%). This proves our hypothesis that a lower seed rate of 60 kg ha$^{-1}$ under ridges and furrows sowing method leads to improved seed yield and seed quality over 70 kg ha$^{-1}$ flatbed sowing method. Hence, a reduced seed rate of 60 kg ha$^{-1}$ under ridges and furrows sowing method has been recommended for realizing optimum soybean seed yield and quality under changing climate scenario.**

**Keywords:** Seed rate, sowing method, phenology, seed quality traits, soybean.

## INTRODUCTION

Soybean [*Glycine max* (L.) Merill], designated as "Wonder crop" has established its potential as an industrially vital and viable oilseed crop in India. It is the world's first-ranking crop as a source of vegetable oil and plays a vital role in fighting the edible oil deficit in the country. The seed rate is an important factor in maintaining the optimum plant population for soybean cultivation. Farmers apply high seed rates and narrow spacing of plants and rows to avoid less plant population risk. The soybean yield is greatly affected by seed rate, so it is necessary to maintain the optimum plant population. More than optimum plant population due to higher seed rate application leads to lodging, ultimately, lower productivity. Higher seed rates enhanced the cost and caused the production of fewer and unfilled pods in the plant, shrinking seed size and reducing crop productivity (Gudge, 2015). A land configuration is a potential tool for soil and moisture conservation. An appropriate land configuration increases crop yield due to increased rainfall infiltration into the soil profile. It becomes available to the crop during prolonged monsoonal breaks and controls water crises in agriculture. Land configuration increases water use efficiency (Chiroma *et al*., 2008) and increases the availability of nutrients to crops. The crop yield in rainfed farming reduces due to excessive soil moisture, and the most important constraint is water logging, reduced oxygen supply, unavailability of hormones to root, and enhanced abiotic stresses during the various growing stages of the crop in rainfed farming (Hariram *et al*., 2012). The flatbed sowing method is popular in the cultivation of soybean crop, which faces water logging, poor aeration, and moisture stress by affecting crop productivity adversely. In the recent past, adverse and erratic weather events like drought and water logging at the time of the highly sensitive grain filling stage caused poor translocation of photosynthates, reduction in green leaf area, and reduced grain filling duration leading to poor seed quality, which hampers germinability of soybean seeds. This problem of seed quality causes a huge gap in the seed supply of soybean in the country. A small change in land configuration in flat field conditions may help improve productivity. To resolve this problem, we hypothesized that reducing the seed rate and sowing in ridges and furrows would stabilize seed yield and quality by better penetration of light and the least damage to seeds due to disease infestation. Keeping all these facts in mind, the present study was designed to investigate the effects of seed rates, sowing methods, and their interaction on phenology, yield, and seed quality traits of soybean.

## MATERIAL AND METHODS

An indeterminate soybean variety JS 20-98 of medium maturity was sown in Experimental Research Farm, Seed Technology Research Unit, JNKVV, Jabalpur during *Kharif* 2019 in Factorial Randomized Block Design with three levels of seed rate *viz*., 70 kg $ha^{-1}$, 60 kg $ha^{-1}$ and 50 kg $ha^{-1}$ and two levels of sowing method *viz.*, Ridge-furrow and Flatbed sowing method with three replications. The plot area was 10 $m^2$ with six rows of five meters row length, and row-row distance is 40 cm. In 70 kg $ha^{-1}$ seed rate, 70 g seeds $plot^{-1}$with 113 seeds $row^{-1}$ with 4.4 cm plant-plant distance was maintained. In 60 kg $ha^{-1}$ seed rate, plant-plant distance is 5.2 cm with 96 seeds $row^{-1}$ and 60 g seeds $plot^{-1}$ was sown. In 50 kg $ha^{-1}$ seed rate, plant-plant distance is 6.2 cm with 80 seeds $row^{-1}$ and 50 g seeds $plot^{-1}$ was sown and maintained. Nitrogen, Phosphorus, and Potassium were added at 20:60:40 kg $ha^{-1}$. The phenological and yield observations were noted from five selected and tagged plants throughout the growth period through daily visual observations. Three replications of 100 seeds from respective treatments were used for germination by using between the paper methods (BP) at 25 ± 20°C in a seed germinator for 8 days at 90% relative humidity (Anonymous, 1999). Two-way ANOVA and Tukey multiple range test was done with the SAS 2.0 statistical software.

## RESULTS AND DISCUSSION

### *A. Phenology as affected by seed rate, sowing method and its interaction*

The early flower initiation was observed in 60 kg $ha^{-1}$ (34.67 days). The minimal increment of 2.05 % on days to flower initiation was observed due to 50 kg $ha^{-1}$ over control (70 kg $ha^{-1}$). With respect to the sowing method, a non-significant difference was observed ($p < 0.05$) for days to flower initiation, whereas, the flat bed sowing method required maximum days to flower initiation (35.59 days), followed by the ridges and furrow sowing method (35.04 days) with an increment of 1.56 %. With respect to the interaction effect, a non-significant difference ($P < 0.05$) was observed for days to first flowering (Table 1). Flower initiation is an important phenological stage that determines plant productivity (Bhattacharya and Sharma, 2001). Late flowering facilitates the enhancement of vegetative growth duration. Early flowering normally promotes the enhancement of the reproductive period, which has been found to be correlated with increased yield in various investigations (Adhikari and Pandey 1982). Seed yield was positively and directly influenced by days to flower initiation (Kumar *et al.,* 2004).

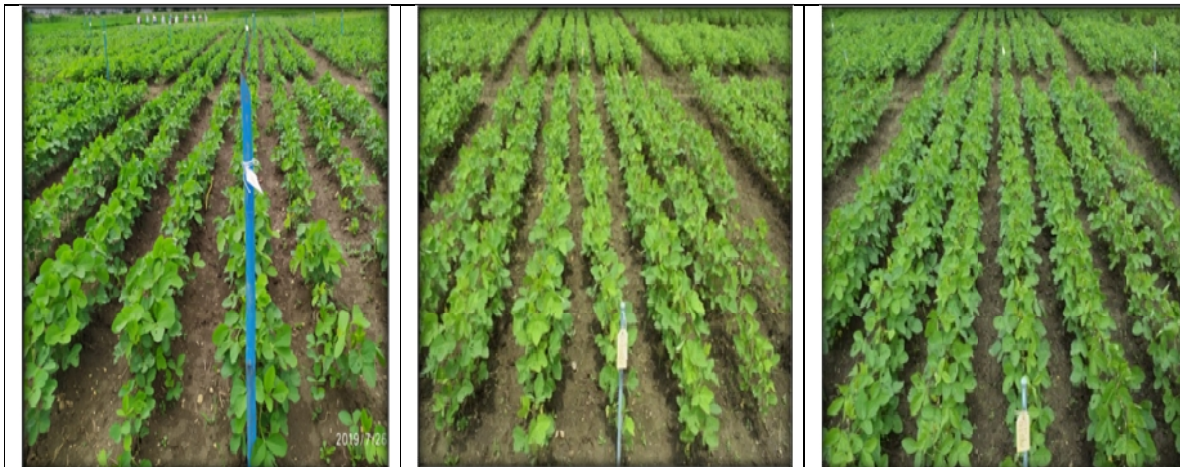
With respect to seed rate, 50 kg $ha^{-1}$ (40.56 days) required more days to attain 50 % flowering, which was at par with 70 kg $ha^{-1}$ (39.56 days). Days to 50% flowering were observed earlier in 60 kg $ha^{-1}$ (38.78 days). The minimal increment of 2.53 % on days to 50% flowering was observed due to 50 kg $ha^{-1}$ over control (70 kg $ha^{-1}$). This might be due to lower plant density and better availability of light and radiation to the canopy in lower seed rates. With respect to the sowing method, flatbed sowing (39.64 days) required increased days to attain 50 % flowering. Ridge and furrow sowing method (39.62 days) recorded lesser number of days for 50% flowering. With respect to seed rate and sowing method interaction, 50 kg $ha^{-1}$ with ridges and furrow sowing method (40.93 days) required increased days to 50 % flowering with a 3.18% increment over control (70 kg $ha^{-1}$ seed rate with flatbed sowing method) (Table 1). During the flowering stage, 18% flowering was found under the prevalent sowing method, while under the ridges and furrow system of plantings, 21% flowering was observed (Bhargav *et al.,* 2013). Hideshima *et al.* (2012) reported that soybean flat and no-tillage cultivation systems resulted in a reduction in flowering time. Furuhata *et al.* (2011) reported that in soybean ridge-cultivation system resulted in reduced flowering.

Seed rate of 50 kg $ha^{-1}$ required maximum time for pod formation (61.43 days), and 60 kg $ha^{-1}$ recorded earlier pod formation with an increment of 0.4% over control (70 kg $ha^{-1}$). With respect to sowing method, the flatbed sowing method required increased days to pod formation, (61.29 days) whereas ridges and furrows (60.74 days) required less days for pod formation. With respect to the interaction effect of seed rate and sowing methods, a non-significant difference ($P < 0.05$) was observed for days to pod formation. As 70 kg $ha^{-1}$ seed rate with ridges and furrow sowing method showed a minimal decrement of 0.32 % over control (70 kg $ha^{-1}$ seed rate with flatbed) for days to pod formation (Table 1). Pod initiation is an important phenological stage sensitive to environmental stress and determines the crop yield in Soybean. Pod formation to the full seed development stage is the most sensitive stage of a soybean crop to all kinds of biotic and abiotic stresses. Rainfall and higher daytime temperature are the most significant weather variables for soybean seed yield under rainfed conditions (Nath *et al.,* 2018). Sesay (1972) found that row spacing influenced days to seed initiation, plant height, and height of the first pod, but not yield.

**Table 1: Effect of seed rate, sowing methods, and its interaction on phenology of Soybean under various treatments.**

| Treatment | Days to flower initiation | Days to 50% flowering | Days to pod formation | Days to seed formation | Days to physiological maturity | Days to harvest maturity |
|---|---|---|---|---|---|---|
| **Seed rate** | | | | | | |
| 70 kg $ha^{-1}$ | $35.28^{a}$ | $39.55^{b}$ | $61.43^{a}$ | $75.45^{b}$ | $90.44^{a}$ | $103.67^{a}$ |
| 60 kg $ha^{-1}$ | $35.83^{a}$ | $38.78^{b}$ | $60.45^{b}$ | $74.95^{b}$ | $89.33^{b}$ | $102.72^{b}$ |
| 50 kg $ha^{-1}$ | $36.00^{a}$ | $40.56^{a}$ | $61.17^{ab}$ | $76.39^{a}$ | $89.84^{ab}$ | $103.77^{a}$ |
| **Sowing method** | | | | | | |
| RF | $35.81^{a}$ | $39.64^{a}$ | $60.74^{a}$ | $75.22^{b}$ | $89.89^{a}$ | $103.33^{a}$ |
| FB | $35.59^{a}$ | $39.62^{a}$ | $61.28^{a}$ | $75.96^{a}$ | $89.85^{a}$ | $103.45^{a}$ |
| **Interaction** | | | | | | |
| 70 kg $ha^{-1}$ + RF | $35.33^{a}$ | $39.44^{ab}$ | $61.33^{ab}$ | $75.00^{b}$ | $70.89^{a}$ | $103.44^{ab}$ |
| 70 kg $ha^{-1}$ + FB | $36.11^{a}$ | $38.55^{b}$ | $59.78^{b}$ | $74.89^{b}$ | $88.99^{a}$ | $102.33^{b}$ |
| 60 kg $ha^{-1}$ + RF | $36.00^{a}$ | $40.93^{a}$ | $61.11^{ab}$ | $75.78^{ab}$ | $89.78^{a}$ | $104.21^{a}$ |
| 60 kg $ha^{-1}$ + FB | $35.22^{a}$ | $39.67^{ab}$ | $61.53^{a}$ | $75.89^{ab}$ | $90.00^{a}$ | $103.89^{ab}$ |
| 50 kg $ha^{-1}$ + RF | $35.55^{a}$ | $39.00^{ab}$ | $61.11^{ab}$ | $75.00^{b}$ | $89.67^{a}$ | $103.11^{ab}$ |
| 50 kg $ha^{-1}$ + FB | $36.00^{a}$ | $40.19^{ab}$ | $61.22^{ab}$ | $77.00^{a}$ | $89.89^{a}$ | $103.33^{ab}$ |

RF: Ridge and furrow sowing method FB: Flatbed sowing method. The values with same letter cases are not significantly different at $p<0.05$ level.



50 kg $ha^{-1}$ seed rate | 60 kg $ha^{-1}$ seed rate | 70 kg $ha^{-1}$ seed rate

**Fig. 1.** Variation in plant population of Soybean JS 20-98.

Seed formation studies revealed that seed rate of 50 kg $ha^{-1}$ (76.33 days) required maximum time for seed formation, which was at par with 70 kg $ha^{-1}$ (75.67 days) with a minimum increment of 0.82%. With respect to sowing method, the flatbed sowing method (75.89 days) required more days for seed formation. In terms of seed rate and sowing method interaction, 50 kg $ha^{-1}$ seed rate with flatbed sowing method showed a minimum increment of 0.88 % over control (70 kg $ha^{-1}$ seed rate with flatbed) for days to pod formation (Table 1). Early seed formation has the advantage of getting more period for seed filling, which leads to enhanced seed productivity, provided the grain filling rate is optimum.

Days to physiological maturity studies revealed that seed rate of 50 kg $ha^{-1}$ required maximum days (90.50 days), and 60 kg $ha^{-1}$ required a lesser number of days to achieve physiological maturity with a minimum increment of 0.80% over control. Flatbed sowing method required maximum days to achieve physiological maturity (90.11 days) with 0.61 % decrement over control (ridges and furrows). In terms of seed rate and sowing method interaction, 50 kg $ha^{-1}$ seed rate with a ridge and furrow sowing method showed similar results over control. A minimal decrement of 1.49% was observed on 60 kg $ha^{-1}$ with a flatbed sowing method and 50 kg $ha^{-1}$ with a flatbed sowing method, respectively (Table 1). After physiological maturity, the dry matter was not partitioned into the sink resulting in reduced productivity as biochemical reactions continue, which may cause the draining of the reserved food material (Gontia *et al.*, 1995). Sakodie *et al.* (2015) observed a highly significant and positive correlation between seed yield with Net Assimilation Rate from pod development to physiological maturity.

Days to field maturity studies revealed that seed rate of 50 kg $ha^{-1}$ recorded a higher duration to achieve maturity (103.77days) with an increment of 0.09% over control. The lowest time for achieving days to field maturity was observed in 60 kg $ha^{-1}$ (102.72 days). With respect to sowing method, the flatbed method (103.44 days) recorded a higher duration to achieve field maturity. The lowest time for achieving harvestable maturity was observed in the ridges and furrow sowing method (103.33) with a 0.11 % decrement. In terms of seed rate and sowing method interaction, 50 kg $ha^{-1}$ seed rate with ridges and furrows sowing method showed a 0.31% increment over control (70 kg $ha^{-1}$ seed rate with flatbed sowing method) (Table 1). The timing of crop maturity is largely determined by the plant's capacity to continue the production of new fruiting sites (Bange and Milroy 2004). The seed yield (g $plant^{-1}$) was significantly and positively correlated with days to maturity (Kumar *et al.*, 2004). Shadakshari *et al*. (2014) reported that among morphological traits under water stress conditions, the days to maturity showed the maximum reduction (94%).

*B. Seed rate, sowing method and its interaction effect on Seed Yield of Soybean*

A significant difference was observed for seed yield g $plant^{-1}$. Maximum seed yield g plant $^{-1}$ was observed in 60 kg $ha^{-1}$ (8.99 g $plant^{-1}$) with a minimum increment of 15.85%, and minimum seed yield (g $plant^{-1}$) was observed for treatment 50 kg $ha^{-1}$ (7.74 g $plant^{-1}$), which was at par with 70kg $ha^{-1}$ (7.76 g $plant^{-1}$). With respect to sowing method, ridges and furrow (8.58 g $plant^{-1}$) possessed higher seed yield $plant^{-1}$ with a 9.79% increment over the flatbed sowing method (7.74 g $plant^{-1}$). With respect to seed rate and sowing method interaction, a significant difference was observed in seed yield $plant^{-1}$. 60 kg $ha^{-1}$ with ridges and furrow sowing method possessed a higher seed yield g $plant^{-1}$ (10.65 g $plant^{-1}$) with an increment of 33.63% over control (70 kg $ha^{-1}$ seed rate with flatbed sowing method) (Table 3). If more seed rate is used, the plant population will be more, and there will be competition among plants for water, nutrient, and sunlight resulting in low quality and low yield. Under lower plant population, radiation and light penetration over the canopy is efficient, leading to higher radiation use, photochemical reaction, photosynthetic rate and chloroplast development, leading to efficient expression of seed yield. Several studies on Soybean indicated that a decrease in plant density produces greater growth of the individual plant (Epler and Staggenborg 2008; Cox *et al.*, 2010; De Luca and Hungria 2014) and consequently more leaf area, branches, pods and seeds per plant (Egli, 1987; Lee *et al.*, 2008; Cox *et al.*, 2010).

The range of seed yield (kg $ha^{-1}$) was found to be 1047.59 – 1597.83 kg $ha^{-1}$. With respect to seed rate, a significant difference was observed in seed yield kg $ha^{-1}$. In terms of seed rate, 60 kg $ha^{-1}$ was found to be superior over 50 kg $ha^{-1}$. 70 kg $ha^{-1}$ (1523.76 kg $ha^{-1}$) possessed a higher seed yield kg $ha^{-1}$. With respect to sowing method, the ridges and furrow sowing method possessed a higher seed yield (1315.65 kg $ha^{-1}$) with an increment of 6.89 % over control. In terms of seed rate and sowing method interaction, 70 kg $ha^{-1}$ seed rate with ridge and furrow sowing method showed a 10.21% increment of seed yield (kg $ha^{-1}$) over control (70 kg $ha^{-1}$ seed rate with flatbed sowing method) (Table 3). Soybean production under the ridge and furrow system of plantings increased seed yield by 10-15% more than that of a prevalent method of planting seeds (Bhargav *et al.*, 2013). Dhakad (2015) studied the effect of raised bed planting on the growth characteristics and yield of Soybean and revealed that the seed yield (1606 kg $ha^{-1}$) recorded significantly higher under raised bed planting compared to normal flatbed sowing (1205 kg $ha^{-1}$), which subsequently resulted in yield enhancement to the extent of 33.3 %.

Biological yield studies revealed that the range of biological yield was found to be from 22.67 g $plant^{-1}$ - 27.33 g $plant^{-1}$. With respect to seed rate, a significant difference was observed on biological yield, seed rate of 50 kg $ha^{-1}$ attained maximum biological yield (26.83 kg $ha^{-1}$) with a minimal increment of 11.00% over control. With respect to sowing method, a significant difference was observed on biological yield. Ridge and furrow sowing method attained maximum biological yield (26.33 g $plant^{-1}$) with 7.59% increment over the flatbed sowing method. In terms of seed rate and sowing method interaction, 60 kg $ha^{-1}$ seed rate with ridges and furrows sowing method showed a 17.15% increment of biological yield over control (70 kg $ha^{-1}$ seed rate with flatbed sowing method) (Table 3). The increment in biological yield under lower plant density might be due to higher radiation and light intensity interception over the canopy leading to higher leaf area and harvest index, consequently causing higher biological yield. Singh *et al.* (2014) reported that permanent bed and zero tillage operation in soybean resulted in higher biological yield as compared to the conventional flatbed methods. A significant difference was observed for biological yield kg $ha^{-1}$. In terms of seed rate, 50 kg $ha^{-1}$ (7225.00) was found to be superior over 60 kg $ha^{-1}$ (6310.00) with a minimal increment of 14.24% over control. In terms of the sowing method, ridges and furrows showed a 14.24% increment in biological yield (kg $ha^{-1}$) over control. In terms of seed rate and sowing method interaction, 60 kg $ha^{-1}$ seed rate with ridges and furrows sowing method showed a 37.16% increment of biological yield (kg $ha^{-1}$) over control (70 kg $ha^{-1}$ seed rate with flatbed sowing method) (Table 3).

Seed yield was significantly and positively correlated with harvest index (Choudhary *et al.*, 2016). With respect to seed rate, 60 kg $ha^{-1}$ possessed a maximum harvest index (35.69%) with an increment of 11.14% over control. With respect to sowing method, maximum harvest index was observed for ridges and furrow sowing method (32.51%). With respect to seed rate and sowing method interaction, maximum harvest index was observed for 60 kg $ha^{-1}$ seed rate with ridges and furrow sowing method (39.03%) with an increment of 11.14% over control (Table 3). Harvest index (HI) was found to be higher in ridges and furrow system as compared to the flatbed system (Basediya *et al*., 2018). Higher harvest index under lower plant density of 60 kg $ha^{-1}$ as compared to 70 kg $ha^{-1}$ might be due to lower plant density, exposure of plants to radiation and light is high, leading to higher leaf area, more electron transport rate, photosynthetic activity per leaf area, no.

of chloroplast per area with efficient partitioning of photoassimilate towards pods or sink leading to higher harvest index.

*C. Effect of seed rate, sowing method and its interaction on seed quality traits of Soybean*

Seed quality is defined as the characteristics that make up attributes of a seed lot that determine seed or seed lot performance (Marcos Filho, 1998). Standard germination is a seed test that measures seed lots ability to emerge and develop under ideal growing conditions and can be predictive of field emergence when field conditions are ideal (Tekrony and Egli 1977). The present study (Table 3) revealed a non-significant effect due to seed rate, sowing method, and interaction on postharvest seed germination, which might be due to compensation of loss of seed quality by seed yield. The present study also revealed that seed vigour i.e., seed vigour index I and II was not affected due to variation in seed rate, sowing method and interaction. The same trend was also observed in seed vigour index II. This might be due to no effect of planting density and sowing method on reserve mobilization towards seeds retaining good seed quality all throughout, which is compensated by loss in seed yield under high-density planting. Kumar and Badiyala (2005) conducted a field trial in which soybean seeds were harvested, consisting of 3 seed rates (60, 75, and 90 kg $ha^{-1}$). Seeds were tested for their germination percentage at an interval of one month from harvest until the next crop season. Saha and Sultana (2008) declared that increasing the soybean seed age and storage duration, germination percent, and seedling field emergence percent would reduce, and finally, seed vigour would reduce. Shelar *et al.* (2008) stated that the soybean seed reaches its maximum potential for germination and vigour at physiological maturity, and the seed is highly susceptible to mechanical injury and damage occurring during postharvest handling, which affects the viability and vigour of soybean seeds during storage.

**Table 2: Results of the Two-way ANOVA and Tukey multiple range tests for the comparative effects of seed rate and sowing method on the Phenology of Soybean.**

| Anova F-values | Days to first flowering | Days to 50% flowering | Days to pod formation | Days to seed formation | Days to physiological maturity | Days to Harvest maturity |
|---|---|---|---|---|---|---|
| Seed rate | 1.39 ns | 9.85 ** | 4.50 * | 6.82** | 3.31 * | 4.73 * |
| Sowing Method | 0.36 ns | 0.01 ns | 3.88 ns | 5.20 * | 0.01 ns | 0.14 ns |
| SR × SM | 0.21 ns | 1.24 ns | 2.01 ns | 1.03 ns | 1.66 ns | 2.73 ns |

*F-values. ns: not significant F ratio (p<0.05); *, ** and *** denotes values are significant at p<0.05, 0.01 and 0.001 levels, respectively.

**Table 3: Effect of seed rate, sowing methods, and its interaction on yield and seed quality traits of Soybean.**

| Treatment | Seed yield | | Biological yield | | Harvest Index (%) | Germination % | Seedling length (cm) | Vigour Index I | Vigour Index II |
|---|---|---|---|---|---|---|---|---|---|
| | g $plant^{-1}$ | kg $ha^{-1}$ | g $plant^{-1}$ | kg $ha^{-1}$ | | | | | |
| **Seed rate** | | | | | | | | | |
| 70 kg $ha^{-1}$ | $7.76^b$ | $3873.7^a$ | $24.17^b$ | $5855.0^a$ | $32.11^{ab}$ | 88.67a | 27.12a | 2384.22a | 37.18a |
| 60 kg $ha^{-1}$ | $8.99^a$ | $3359.4^a$ | $25.00^{ab}$ | $6310.0^{ab}$ | $35.69^a$ | 87ab | 27.76a | 2250.52a | 31.85a |
| 50 kg $ha^{-1}$ | $7.73^b$ | $2555.3^b$ | $26.83^a$ | $7225.0^a$ | $28.91^b$ | 85.67b | 25.91a | 2443.86a | 34.4a |
| **Sowing method** | | | | | | | | | |
| RF | $8.58^a$ | $3337.4^a$ | $26.33^a$ | $6958.9^a$ | $32.51^a$ | 87.78a | 27.23a | 2376.86a | 36.38a |
| FB | $7.74^a$ | $3188.2^a$ | $24.33^b$ | $5967.8^b$ | $31.96^a$ | 83.78a | 26.63a | 2342.21a | 32.57a |
| **Interaction** | | | | | | | | | |
| 70 kg $ha^{-1}$ + RF | $7.55^b$ | $3728.48^{ab}$ | $25.00^{ab}$ | $6256.67^{ab}$ | $30.12^b$ | 89.33a | 27.51a | 2533.05a | 40.01a |
| 60 kg $ha^{-1}$ + RF | $10.65^a$ | $3811.26^{ab}$ | $27.33^a$ | $7480.00^a$ | $39.03^a$ | 80a | 26.73a | 2235.39a | 34.35a |
| 50 kg $ha^{-1}$+ RF | $7.55^b$ | $2472.37^b$ | $26.67^{ab}$ | $7140.00^{ab}$ | $28.37^b$ | 87.33a | 28.13a | 2216.67a | 30.64a |
| 70 kg $ha^{-1}$ + FB | $7.97^b$ | $4018.89^a$ | $23.33^{ab}$ | $5453.33^{ab}$ | $34.10^{ab}$ | 86.67a | 27.4a | 2284.37a | 33.05a |
| 60 kg $ha^{-1}$ + FB | $7.33^b$ | $2907.47^{ab}$ | $22.67^b$ | $5140.00^b$ | $32.35^{ab}$ | 86.7a | 26.05a | 2380.85a | 38.49a |
| 50 kg $ha^{-1}$ + FB | $7.92^b$ | $2638.13^{ab}$ | $27.00^a$ | $7310.00^a$ | $29.45^b$ | 84.67a | 25.77a | 2506.87a | 30.3a |

RF: Ridge and furrow sowing method FB: Flatbed sowing method. The values with same letter cases are not significantly different at p<0.05 level.

**Table 4: Results of the Two-way ANOVA and Tukey multiple range tests for the comparative effects of seed rate and sowing method on yield and seed quality traits of Soybean.**

| F value | Seed yield | | Biological yield | | HI (%) | Germination % | Seedling Length(cm) | Vigour index I | Vigour index II |
|---|---|---|---|---|---|---|---|---|---|
| | g $plant^{-1}$ | kg $ha^{-1}$ | g $plant^{-1}$ | kg $ha^{-1}$ | | | | | |
| Seed rate | 4.16* | 10.05 ** | 5.49* | 5.33* | 7.09** | 2.83 ns | 0.01 ns | 0.91 ns | 1.40 ns |
| Sowing Method | 4.27 ns | 0.38 ns | 8.85** | 8.06 ** | 0.14 ns | 0.53 ns | 0.02 ns | 0.08 ns | 2.15 ns |
| SR × SM | 9.26** | 2.45 ns | 4.67* | 4.38* | 4.67 * | 3.58 ns | 0.78 ns | 1.23 ns | 1.50 ns |

*F-values. ns: not significant F ratio (p<0.05); *, ** and *** denotes values are significant at p<0.05, 0.01 and 0.001 levels, respectively.

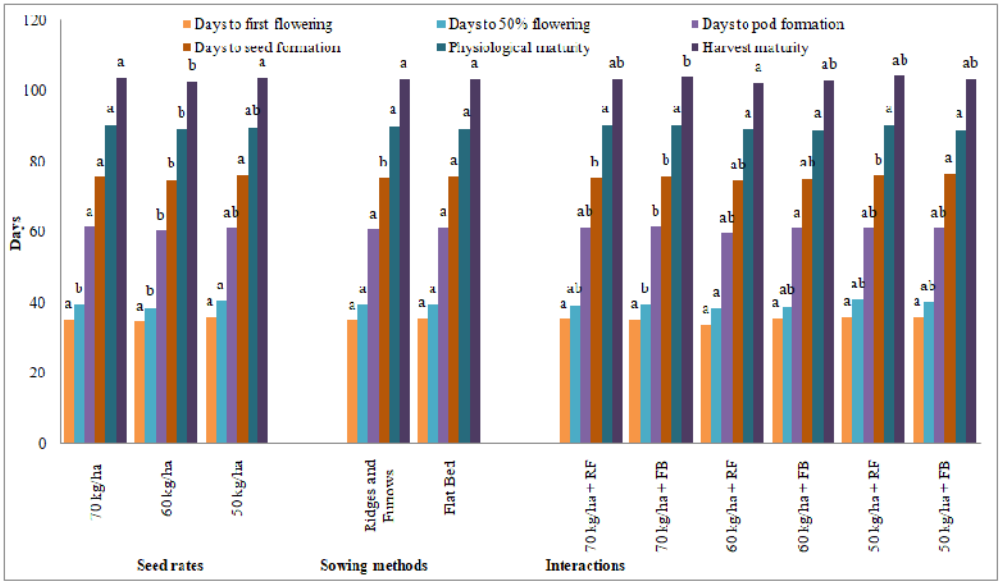



**Fig. 1.** Phenophases in soybean during reproductive growth periods under various treatments: column with same letter were not significantly different at P<0.05.

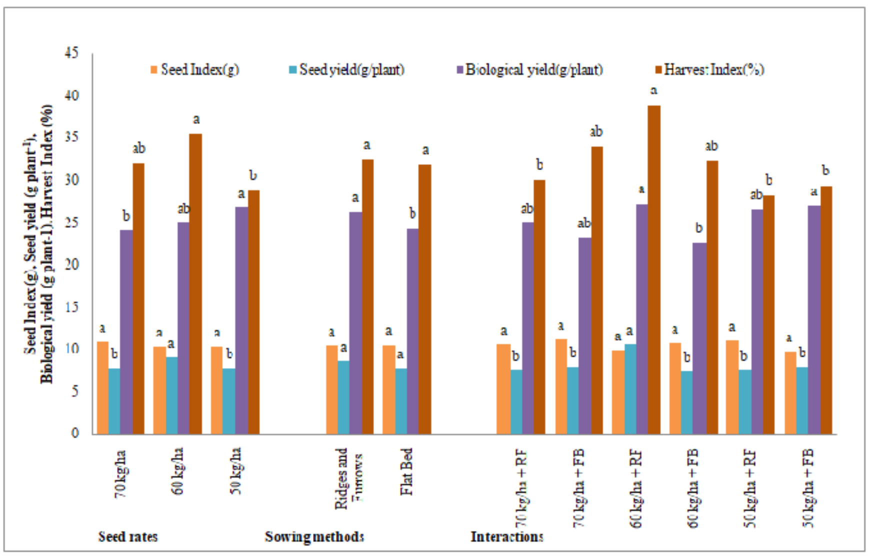



**Fig. 2.** Various yield attributes of soybean under various treatments: column with same letter were not significantly different at P<0.05.

## CONCLUSION

Seed yield (g plant$^{-1}$) is maximum at a reduced seed rate of 60 kg ha$^{-1}$ due to reduced days to flower initiation, pod formation, and seed formation, physiological maturity and harvest maturity. Seed yield (g plant$^{-1}$) is superior for ridges and furrows over the flatbed sowing method by 9.79%. The superiority of lower seed rate in seed yield per plant is due to the rapid progression of phenological stages, which might be due to lower plant density and better availability of light and radiation to the canopy. Seed yield (kg ha$^{-1}$) is maximum at a higher seed rate of 70 kg ha$^{-1}$ due to the higher plant population. Seed quality attributes *viz.*, germination percentage and seedling length, seed vigour, *i.e.*, seed vigour index I and II are not affected due to variation in seed rate, sowing method, and interaction.

## FUTURE SCOPE

The identified reduced seed rate of 60 kg ha$^{-1}$ and ridge and furrow sowing method will reduce the input cost associated with seed without compromising seed quality and seed yield. Hence, the seed rate of 60 kg ha$^{-1}$ seed rate and ridge and furrow sowing method will be recommended to the farmers to get optimum soybean seed yield and quality.

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## REFERENCES


Adhikari, G. and Pandey, M. P. (1982). Genetic variability in some quantitative characters on scope for improvement in chickpea (*Cicer arietinum* L). Chickpea Newsletter, June Icn, *7*, 4-5.

Bange, M. P. and Milroy, S. P. (2004). Growth and dry matter partitioning of diverse cotton genotypes. *Field Crops Research*, *87*(1), 73-87.

Basediya, A. L., Mishra, S., Gupta, R., Kumar, P. and Basediya, S. S. (2018). Performance of ridge and furrow system on the growth and yield attribution of soybean in Barwani District of MP India. *International Journal of Current Microbiology and Applied Sciences*, *7*(8), 499-505.

Bhargav, K. S., Jain, V. K. and Rajiv, U. (2013). Ridge and furrow system of planting seeds: a water management approach for increased soybean production in Madhya Pradesh. *Journal of Interacademicia*, *17*(2), 245-253.

Bhattacharya, A. and Sharma, D. K. (2001). Flower drop in Pigeonpea: Effect of physiological traits under normal and late seeding. *Legume Research-An International Journal*, *24*(4), 231-237.

Chiroma, A. M., Alhassan, A. B. and Khan, B. (2008). Yield and water use efficiency of millet as affected by land configuration treatments. *Journal of Sustainable Agriculture*, *32*(2), 321-333.

Chowdhury, J. A., Karim, M. A., Khaliq, Q. A., Ahmed, A. U. and Khan, M. S. A. (2016). Effect of drought stress on gas exchange characteristics of four soybean genotypes. *Bangladesh Journal of Agricultural Research*, *41*(2), 195-205.

Cox, W. J., Cherney, J. H. and Shields, E. (2010). Soybeans compensate at low seeding rates but not at high thinning rates. *Agronomy Journal*, *102*(4), 1238-1243.

Dhakad, S. S., Badaya, A. K., Chauhan, S. S. and Gathiye, G. S. (2015). Effect of ridge and furrow system on the growth character and yield in rainfed soybean in Madhya Pradesh. *Indian Journal of Ecology*, *42*(1), 230-232.

Egli, D. B., Wiralaga, R. A., Bustamam, T., Zhen Wen, Y. and TeKrony, D. M. (1987). Time of Flower Opening and Seed Mass in Soybean 1. *Agronomy Journal*, *79*(4), 697-700.

Epler, M. and Staggenborg, S. (2008). Soybean yield and yield component response to plant density in narrow row systems. *Crop management*, *7*(1), 1-13.

Furuhata, M., Adachi, K. and Ohono, S. (2011). Influence of field drainage on dry matter and seed production of soybean in the Hokuriku district of Japan. *Japanese Journal of Crop Science*, *80*(1), 65-72.

Gontia, A. S., Nigam, P. K., Sonakia, V. K., and Dwivedi, S. K. (1995). Identification of morphological indices of physiological maturity in soybean (*Glycine max*) genotypes. *Indian Journal of Agricultural Sciences* (India).

Gudge, A., Rawat, G. S. and Tiwari, S. (2015). Impact of conservation agriculture and nitrogen management on growth and productivity of maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry*, *8*(4), 2260-2264.

Hariram, Singh, G., Aggarwal, N., and Kaur, J. (2011). Soybean (*Glycine max*) growth, productivity and water use under different sowing methods and seeding rates in Punjab. *Indian Journal of Agronomy*, *56*(4), 377.

Hideshima, Y., Makiyama, S., Mori, K. and Ichimaru, Y. (2012). Effect of field drainage and sowing density on growth and yield of soybean in the flat and no-tillage cultivation. *Report of the Kyushu Branch of the Crop Science Society of Japan*, (78), 16-18.

Kumar, J. and Badiyala, D. (2005). Influence of seed rate, spacings, date of sowing and storage containers on storability of soybean (*Glycine max* (L.) Merr.). *Legume Research*, *28*(4), 309-320.

Kumar, R., Kant, R. and Ojha, C. B. (2004). Character association and cause effect analysis for spring season genotypes of mung (*Vigna radiata* L.). *Legume Research-An International Journal*, *27*(1), 32-36.

Lee, C. D., Egli, D. B. and TeKrony, D. M. (2008). Soybean response to plant population at early and late planting dates in the Mid-South. *Agronomy Journal*, *100*(4), 971-976.

Luca, M. J. D. and Hungria, M. (2014). Plant densities and modulation of symbiotic nitrogen fixation in soybean. *Scientia Agricola*, *71*, 181-187.

Marcos-Filho, J. (1998). New approaches to seed vigor testing. *Scientia Agricola*, *55*, 27-33.

Nath, A., Karunakar, A. P. and Kumar, A. (2018). Study of the Relationship between Various Weather Variables and Final Seed Yield of Soybean Crop during Different Phenological Stages in the Akola Region of Vidarbha, India. *International Journal Current Microbiology Applied Sciences*, *7*(9), 1027-1031.

Saha, R. R. and Sultana, W. (2008). Influence of seed ageing on growth and yield of soybean. *Bangladesh Journal of Botany*, *37*(1), 21-26.

Sakodie, A., S., Owusu, P. A. and Jayaweera, M. (2015). Flood risk management in Ghana: A case study in Accra. *Advances in Applied Science Research*, *6*(4), 196-201

Sesay, A. (1972). Characteristics of soybean varieties grown in various date of plant-row spacing-plant population combinations (Doctoral dissertation, Iowa State University).

Shadakshari, T. V., Yathish, K. R., Kalaimagal, T., Gireesh, C., Gangadhar, K. and Somappa, J. (2014). Morphological response of soybean under water stress during pod development stage. *Legume Research-An International Journal*, *37*(1), 37-46.

Shelar, V. R., Shaikh, R. S. and Nikam, A. S. (2008). Soybean seed quality during storage: a review. *Agricultural Reviews*, *29*(2), 125-131.

Singh, R. C., Dashrath, S., Singh, C. D. and Vikas, G. (2014). Yield response to bed sowing of soybean and wheat crop in zero tillage with crop residue. *Green Farming*, *6*(1), 55-58.

TeKrony, D. M. and Egli, D. B. (1977). Relationship Between Laboratory Indices of Soybean Seed Vigor and Field Emergence 1. *Crop Science*, *17*(4), 573-577.



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