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Effect of sowing time and spacing on yield and seed quality of dhaincha {*Sesbania aculeata* (Willd.) Pers.} During post rainy season

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Abstract
A field experiment was conducted during post rainy season (January to June) of consecutive years 2021 and 2022 at Research Cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh with the objective to find out effect of sowing time and spacing on yield and seed quality of dhaincha in sandy clay loam soil of Chhattisgarh plain. The experiment was laid out in split plot design with four main plot (Sowing time) and four sub plots (spacing) with three replications. The main plot comprises of four sowing dates, D_1- 10th January, D_2- 20th January, D_3- 30th January and D_4- 09th February. And sub plot comprises four spacing treatments of S_1- 30 x 10 cm, S_2- 30 x 20 cm, S_3- 45 x 10 cm and S_4- 45 x 20 cm. The results revealed that sowing of dhaincha at 20th January (D_2) recorded the maximum value on yield attributing characters (total number of pods plant^{-1}, number of seeds pod^{-1}, pod length and test weight), seed yield, straw yield, graded seeds, undersized seeds and germination percent. This sowing date also shows highest value of gross return, net return and benefit cost ratio. As far as spacing treatments in dhaincha crop is concerned, yield attributing characters like total number of pods plant^{-1}, number of seeds pod^{-1}, pod length and test weight (1000 seed weight) was found highest, when crop was sown with wider spacing of 45 x 20 cm (S_4). Seed yield, straw yield and seed quality characters like quantity of graded seeds, undersized seeds, germination percent was found maximum when dhaincha was sown at spacing of 30 x 20 cm (S_2). This spacing also shows maximum gross return, net return and benefit cost ratio. As far as interaction effect was concerned, total number of pods plant^{-1} was found highest with sowing on 20th January (D_2) at wider spacing crop of 45 x 20 cm (S_4). While other yield attributes like number of seeds pod^{-1}, pod length and test weight did not differ significantly due to combine effect of sowing date and spacing. Seed yield, straw yield, graded seeds and germination percent of dhaincha as affected by different sowing date and spacing was found maximum when crop sown on 20th January (D_2) with 30 x 20 cm (S_2) spacing.

Keywords: Sowing time, spacing, seed yield, seed quality, dhaincha *Sesbania aculeata* (Willd.) Pers

Introduction
Almost all green manure crops which are used for *in-situ* or *ex-situ* green manuring contain all the plant nutrients which are essential for completing the life cycle of any plant species. The main green manure crops grown in India are Dhaincha, Sunhemp, Wild Indigo, Pillipesara, Cowpea, Cluster bean (Guar), Green gram (Mung bean) and Berseem.

Of the various in situ green manuring crops in India, dhaincha [*Sesbania aculeata* (Willd.) Pers.] have higher accumulation of major and micro nutrients on account of more biomass production and better nutrient composition compared to food legumes which are inferior due to low content of nutrients coupled with less dry matter production. It is the cheapest and best source for improving soil fertility and maintaining the health of an agro-ecosystem. The ease of establishment, quick germinating, fast growth, succulency, easily decomposable with low water requirement that produces maximum amount of biomass within a short period, rich in nutrients especially nitrogen (3.5%), Phosphorus (0.6%) and Potassium (1.2%), bears more number of nodule (Carlsson and Huss-Danell, 2003) [1], quick decomposition upon incorporation in paddies (puddle rice lands) and can release nutrients as per the need of rice crop, made dhaincha the most ideal and widely grown green manure crop particulary in rice cultivated areas in India (Palaniappan and Siddeswaran, 2001) [6]. Further, it is promising for cultivation in salt affected ill drained soils and areas with high rainfall (Parlawar *et al.*, 2003) [7].

Green manure crops are mostly grown for biomass production of green matter, which is incorporated prior to its flowering phase. Though the value of green manure crops in supplementing nutrients is well established, but the practice of green manuring is not being widely adopted by the farmers due to multiple factors. For producing sufficient quantity of green manure biomass, the use of quality seed is of great significance. But the availability of adequate amount of good quality seed at reasonable price and at the appropriate time in the market is the foremost and most significant agronomic constraint limiting green manure usage.

Scarcity of seed is the main limiting factor for both farmers and government and quick expansion of dhaincha green manuring. To tackle the problem of timely supply of green manure crop seed especially *Sesbania aculeata*, the government of Chhattisgarh has been procuring the seed from neighboring states by allocating huge funds for seed purchase. Dhaincha seed production is mainly concentrated in peninsular India and by the time its seed reaches Central India, the prices rise beyond purchase of seed and seed quality is not ensured. The protein rich dhaincha seed as an animal feed (Hossain *et al*., 2001) [2] also demands production of more seed. Hence, timely production and supply of green manure crop seeds especially "*Sesbania aculeata*" at cheapest rates in the state has been given the priority for procurement of the seed and to make it available well in advance to the farmers. The availability of seed in the market depends on its multiplication but the farmers are perplexed regarding its agronomical practices like date of optimum sowing and crop geometry.

Information on agro-techniques like optimum time of sowing and plant spacing for increased productivity of good quality seed of dhaincha are not available to the farmers. A lot of work on its utility as green manure crop has been done. But so far no serious attempt has been made to grow dhaincha as seed crop with good agronomical management tool. Hence for realizing higher yield, its seed production technology has to be standardized in terms of optimum sowing time, crop geometry and other cultural practices.

Keeping the above fact in view, the present investigation was conducted during post rainy season (January to June) of consecutive years 2021 and 2022 at Research Cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh with the objective to find out effect of sowing time and spacing on yield and seed quality of dhaincha.

Materials and Methods

The experiment was laid out in split plot design with with four main plot (Sowing time) and four sub plots (spacing) with three replications. The main plot comprises of four sowing dates, D_1- 10th January, D_2- 20th January, D_3- 30th January and D_4- 09th February. And sub plot comprises four spacing treatments of S_1- 30 x 10 cm, S_2- 30 x 20 cm, S_3- 45 x 10 cm and S_4- 45 x 20 cm. The soil aggregates of experimental field was sandy clay loam in texture with bulk density of 1.17 Mg m^{-3}, neutral in pH (7.34) and had good electrical conductivity of 0.25 d s m^{-1}. The soil was low (191.28 kg ha^{-1}) in available nitrogen, medium (16.37 kg ha^{-1}) in available phosphorus and medium in (294.76 kg ha^{-1}) available potash. Dhaincha crop treated seeds was sown in line manually with different spacings (in sub plots) as per the treatments starting from 10th January to 9th February of consecutive year of 2021 and 2022 (in main plots) with recommended dose of fertilizer (20:50:30 kg NPK ha^{-1}). Number of seeds pod^{-1}, pod length, test weight, seed yield, stover yield were recorded and mean values were subjected to analysis. In order to obtained quality and identical seeds of dhaincha crop, seed yield of each net plot were graded by using 3.25 mm sieve (screens with elongated perforations) upside and 1.25 mm elongated sieve downward, and the quantity of graded seeds obtained was noted down, and then calculated or expressed in kg ha^{-1}.

The laboratory test for germination of dhaincha seed was conducted as per the International Seed Testing Association Rules (ISTA, 2011) [3] by adopting Between Paper (BP) method. Seeds from pure seed fraction were used for determination of germination percentage. One hundred seeds each in two replications were taken from each treatment and uniformly placed in between two layers of sufficiently moistened rolled paper towels or germination paper which was then rolled and wrapped in a sheet of wax paper so as to keep the surface evaporation to minimum and placed in germination chamber in an upright position. The rolled towel was kept in the seed germinator maintained at constant temperature of 25 ± 1 °C and 95% relative humidity for seven days. The first count and final count were taken on fourth and seventh day, respectively. On the day of final count, the number of seeds germinated as normal seedlings were counted and the percent seed germination was calculated as follows:

$$\text{Seed Germination (\%)} = \frac{\text{Number of germinated seedlings}}{\text{Total number of seeds plated}} \text{X} 100$$

Results and Discussions

Number of seeds pod^{-1}

The data on number of seeds pod^{-1} of dhaincha under various sowing date and spacings have been presented in Table 1. The data revealed that number of seeds pod^{-1} was influenced due to different sowing date as well as spacing

Effect of sowing date

Number of seeds pod^{-1} was highly influenced by different sowing dates in dhaincha. The number of seeds pod^{-1} (31.61 and 32.22) during 2021 and 2022, respectively of dhaincha was highest with the 20th January (D_2) sowing date and differed significantly from remaining sowing dates. Whereas the 10th January (D_1) sowing date recorded significantly lowest number of seeds pod^{-1} (21.56 and 22.70) during 2021 and 2022, respectively. Early sowing (10th January) of dhaincha during post rainy season once again proved inferiority in producing more seeds pod^{-1}. 20th January (D_2) sown plants enjoyed favourable weather for proper growth resulting in more plant vigour. Whereas in contrary early sowing of 10th January (D_1) owing to poor growth in terms of plant height, drymatter production, which might have resulted in poor translocation of food reserves leading to less number of seeds pod^{-1}. The decrease in number of seeds pod^{-1} under early sowing of 10th January (D_1) was 31.79% and 29.55% during 2021 and 2022, respectively.

Effect of spacing

Data pertaining to number of seeds pod^{-1} of dhaincha as influenced by different spacing treatments revealed that more number of seeds pod^{-1} (31.20 and 31.73) during 2021 and

2022, respectively with mean of 31.47 seeds per pod^{-1} was resulted due to wider spacing of 45 x 20 cm (S_4) over other spacings treatment and was found significantly higher than any other treatments. The lowest number of seeds pod^{-1} was counted with closer spacing of 30 x 10 cm (S_1). The decrease in number of seeds pod^{-1} under closer spacing of 30 x 10 cm (S_1) was 29.81% and 28.27% during 2021 and 2022, respectively as compared to wider spacing of 45 x 20 cm (S_4). Similarly, 30 x 20 cm (S_2) spaced crop decrease the number of seeds pod^{-1} by 13.75% in 2021 and 12.80% in 2022 and sowing crop with 45 x 10 cm (S_3) decrease the number of seeds pod^{-1} by 6.12% and 4.38% in 2021 and 2022, respectively.

Wider spacing of 45 x 20 cm (S_4) was optimum to strike a balance between external (environment) and internal (plant) factors for increasing the seed number pod^{-1}. Quite a number of researchers, Parlawar *et al.* (2001) [9], Ulemale *et al.* (2002) [14], Lamani *et al.* (2004) [5], Shastri *et al.* (2007) [13] and Sangeetha *et al.* (2011) [12] Found Similar Results.

Interaction effect

The interaction effect of sowing dates and spacing on dhaincha did not show any significant effect on number of seeds pod^{-1}.

Pod length (cm)

The data on pod length of dhaincha was recorded under various sowing date and spacing treatments and have been presented in Table 1. The data revealed that the pod length of dhaincha was influenced significantly due to different sowing date and spacing but its interaction effect was found non-significant.

Effect of sowing date

Data pertaining to pod length of dhaincha due to different sowing date resulted in significant variations. The longest pod length (20.71 cm and 21.88 cm) was recorded on plots in which dhaincha is sown on 20th January (D_2) during both the year of study, and was found statistically maximum over other sowing dates. Sowing of dhaincha on 10th January (D_1) and 30th January (D_3) recorded similar results and was found statistically at par with each other during both the experimental year. The shortest pod length (17.28 cm and 18.61 cm in 2021 and 2022, respectively) during study was recorded with late sown crop on 09th February (D_4) and was found statistically inferior among other sowing dates.

Effect of spacing

Pod length of dhaincha recorded due to different spacing treatments was also found significant. The length of pod increases with increase in inter and intra row spacing. The longer pod length (21.95 cm and 23.42 cm) of dhaincha crop with mean of 22.68 cm, due to various spacing treatment was measured with the crop sown in wider spacing of 45 x 20 cm (S_4) and it was found significantly superior over rest other spacings followed by sowing with 45 x 10 cm (S_3) and 30 x 20 cm (S_2). The shorter pod length (15.04 cm and 15.71 cm) during 2021 and 2022, respectively of dhaincha was recorded with crop sown on closer spacing of 30 x 10 cm (S_1). Similar results was also observed by Rajesh *et al.* (2017) [10] in which they stated that wider spacing produces longer pod than closer spacing in dhaincha.

Interaction effect

The interaction effect of sowing dates and spacing on dhaincha did not show any significant effect on pod length.

Test weight (1000 seed weight)

Test weight (1000 seed weight) of dhaincha was significantly influenced by different sowing dates and spacings but not by their interaction (Table 1).

Effect of sowing date

Data on effect of sowing date on test weight of dhaincha seed revealed that test weight decreased significantly with every 10 days delay in sowing during 20th January to 09th February. Among the different dates of sowing, sowing of dhaincha on 20th January (D_2) recorded the highest test weight (21.07 g and 21.29 g) during 2021 and 2022, respectively, of dhaincha, which was significantly superior over either early or delayed sowings. More test weight under this sowing date might be due to the enhanced translocation of food reserves leading to better seed filling and bold seeds. The next best time of sowing with respect to test weight was 30th January (D_3) which was found statistically at par with 09th February (D_4) sowing date.

These results were in accordance with Kumar *et al.* (2006) [4] in dhaincha. The lowest test weight recorded with sowing on 10th January (D_1) was mainly due to reducing the grain growth duration, which in turn results in reduced test weight. The same information is also elicited by Ulemale *et al*. (2002) [14] and Kumar *et al*. (2006) [4].

Effect of spacing

Data pertaining to effect of spacing on test weight of dhaincha revealed that crop sown with wider spacing produces heavier seed than that of closer spacing. A significant increase in test weight (20.53 g) was with wider spacing of 45 × 20 cm (S_4) sown dhaincha crop and was found significantly higher than any other spacing treatment during 2021, but during second year (20.88 g) and on year mean basis (20.71 g), it was found at par with crop sown on spacing of 45 x 10 cm (S_3) in respect to test weight. The lowest test weight (17.94 g and 18.33 g) of dhaincha during 2021 and 2022, respectively as influenced by spacing was recorded with closer spacing of 30 x 10 cm (S_1) with yearly mean weight of 18.14 g.

At higher plant densities in closer spacing dhaincha crop, inter - plant competition for light, space and nutrients were more and thereby affecting the translocation of assimilates for efficient filling of grains. These results are in conformity with those reported by Rengalakshmi and Purshothaman (1999) [11] and Yaragoppa *et al.* (2003) [15] in dhaincha.

Interaction effect: The interaction effect of dates of sowing and spacing in dhaincha crop did not show any significant impact on its test weight.

Seed Yield (kg ha^{-1})

The data pertaining to seed yield of dhaincha as influenced by different sowing dates, spacings and their interaction effect are presented in Table 2 and Table 3. The perusal of the data indicated that the difference in seed yield of dhaincha due to different sowing date and spacing was found significant.

Effect of sowing date

Seed yield of dhaincha tend to decrease significantly with

every 10 days shifting in sowing from 20th January to 09th February. Among the different dates of sowing, sowing of dhaincha on 20th January (D_2) recorded the highest seed yield of 1191 kg ha^{-1} and 1276 kg ha^{-1}, during 2021 and 2022, respectively, which was significantly superior over either early or later two sowing dates. However, it was found statistically at par with sowing of dhaincha on 30th January (D_3) with seed yield of 1043 kg ha^{-1} during 2021 and 1112 kg ha^{-1} during 2022. The decrease in seed yield under early sowing of 10th January (D_1) was 33.08% and 35.03% during 2021 and 2022, respectively against the best date of 20th January (D_2). Similarly, delayed sowing beyond 20th January (D_2) decreased the seed yield by 12.43% and 12.85% when sown on 30th January (D_3) and 18.14% and 15.75% when sown on 9th February (D_4) during 2021 and 2022, respectively.

Significantly higher seed yield with 20th January (D_2) over early or delayed sowing dates might be due to partitioning of higher proportion of its total dry matter into the reproductive parts (seed) of the plant. Added to the above, better growth and development of crop at this date when compared to other dates of sowing in all aspects might have reflected in better yield expression.

On the other hand, significantly the minimum seed yield of 797 kg ha^{-1} and 829kg ha^{-1} during 2021 and 2022, respectively, was recorded when the crop was sown on 10th January (D_1) compared to other dates.

Effect of spacing

Data pertaining to seed yield of dhaincha as influenced by different spacing was found significant. Significantly higher seed yield (1238 kg ha^{-1} and 1342 kg ha^{-1}) during 2021 and 2022, respectively with year mean of 1290 kg ha^{-1} was produced with spacing of 30 x 20 cm (S_2) and was found superior over rest of the other spacing treatments. On the contrary, the lowest seed yield of 822 kg ha^{-1} in 2021 and 871 kg ha^{-1} in 2022 with year mean of 847 kg ha^{-1} was obtained at wider spacing of 45 x 20 cm (S_4).The decrease in seed yield under closer spacing of 30 x 10 cm (S_1) was 19.71% and 19.97% during 2021 and 2022, respectively as compared to best spacing of 30 x 20 cm (S_2). Similarly, wider inter spaced crop of 45 x 10 cm (S_3) decrease the seed yield by 23.10% in 2021 and 25.19% in 2022 and sowing crop with 45 x 20 cm (S_4) decrease the seed yield by 33.60% and 35.10% in 2021 and 2022, respectively.

Though, all the yield attributing characters were higher at wider spacings, these improvements were not sufficient to compensate the yield that obtained due to higher plant population per unit area. Similar increase in seed yield at closer spacing was also reported by Yaragoppa *et al.* (2003) [15] and Kumar *et al.* (2006) [4].

Interaction effect

The interaction between sowing dates and spacing was significantly influenced in dhaincha seed yield and was presented in Table 3. Data revealed that the seed yield of dhaincha significantly decreased with delay in sowing from 20th January to 09th February with all the four spacings studied during both the year of experiment but early sowing *i.e* 10th January with all spacing recorded the lowest seed yield. Significantly, the maximum seed yield of 1518 kg ha^{-1} in 2021 and 1635 kg ha^{-1} in 2022 with year mean of 1577 kg ha^{-1} of dhaincha was produced with 20th January (D_2) sowing date at a spacing of 30 x 20 cm (S_2) and this proved superior over the rest of all treatment combinations of sowing date and spacings. On the other hand, the lowest seed yield of 760 kg ha^{-1} in 2021 and 766 kg ha^{-1} was produced with 10th January (D_1) sowing date at wider spacing of 45 x 20 cm (S_4). However, it was found statistically comparable and at par result with sowing date of 10th January (D_1) at spacing of 45 x 10 cm (S_3) and 30 x 10 cm (S_1).

Stover yield (kg ha^{-1})

The data pertaining to stover yield of dhaincha as influenced by different sowing dates and spacings and its interaction effects are presented in Table 2 and 3. Data revealed that there is a significant variations in dhaincha stover yield when grown with different sowing time with different spacing treatments.

Effect of sowing date

The data regarding effect of sowing dates on stover yield of dhaincha was found significant due to sowing date variations. Significantly, the highest stover yield of dhaincha (7878 kg ha^{-1} and 8587 kg ha^{-1}) during 2021 and 2022, respectively was recorded with 20th January (D_2) sowing date and was found significantly highest among rest of the other sowing dates. However, this was found statistically at par with sowing date of 30th January (D_2) with stover yield of 7282 kg ha^{-1} in 2021 and 7882 kg ha^{-1} in 2022. The decrease in stover yield under early sowing of 10th January (D_1) was 36.46% and 38.25% during 2021 and 2022, respectively against the best date of 20th January (D_2). Similarly, delayed sowing beyond 20th January (D_2) decreased the seed yield by 7.57% and 8.21% when sown on 30th January (D_3) and 17.95% and 17.29% when sown on 9th February (D_4) during 2021 and 2022, respectively. The lowest stover yield of dhaincha (5006 kg ha^{-1} and 5302 kg ha^{-1} during 2021 and 2022, respectively) with respect to sowing dates was recorded with 10th January (D_1) sowing and was mainly due to reduced plant stature.

Effect of spacing

Stover yield of dhaincha differed significantly among the different spacings. Among different spacings, Stover yields decreased with an increase in plant spacing. Significantly, the maximum stover yield (7346 kg ha^{-1} in 2021 and 7930 kg ha^{-1} in 2022) was produced at closer optimum spacing of 30 x 20 cm (S_2) and this was significantly higher when compared to other spacing treatments. This may be due to the higher but optimum plant population at above said spacing than much closer and wider spacing combination. On the contrarily, minimum stover yield of dhaincha was obtained with wider spacing 45 x 20 cm (S_4) with 6003 kg ha^{-1} of mean year value. The decrease in stover yield under closer spacing of 30 x 10 cm (S_1) was 5.64% and 4.79% during 2021 and 2022, respectively as compared to best spacing of 30 x 20 cm (S_2). Similarly, wider inter spaced crop of 45 x 10 cm (S_3) decrease the seed yield by 10.20% in 2021 and 9.99% in 2022 and sowing crop with 45 x 20 cm (S_4) decrease the seed yield by 21.67% and 21.15% in 2021 and 2022, respectively.

Interaction effect

The interaction effect between sowing dates and spacings in dhaincha with respect to stover yield was found significant in first year of experiment only, and presented in tabular data (Table 4). The data revealed that dhaincha sown on 20th January (D_2) with spacing of 30 x 20 cm (S_2) produced higher stover yield (8736 kg ha^{-1} and 9518 kg ha^{-1} in 2021 and 2022,

respectively) and was found significantly higher than any other combination of sowing dates and spacing treatments. However, during 2021, statistically similar stover yield of dhaincha was obtained with sowing of dhaincha on 20th January (D_2) with spacing of 30 x 10 cm (S_1) and sowing on 30th January (D_3) with 30 x 20 cm (S_2) spacing. On the other hand, the lowest stover yield of dhaincha was produced with 10th January (D_1) sowing date at wider spacing of 45 x 20 cm (S_4) and was significantly the lowest as compared to all other treatment combinations of sowing date and spacing. The advantage of combining effect of factors for enhanced straw yield also followed the same trend as was observed and discussed under seed yield.

Quantity of graded seeds (kg ha^{-1})

Data with respect to quantity of graded seeds of dhaincha as influenced by sowing dates and spacings was found significant and presented in Table 4 and its interaction effect was also significantly differ (table 5).

Effect of sowing date

Significantly results were obtained in quantity of graded seeds of dhaincha as influenced by sowing dates. As regards to different sowing dates, the maximum graded seeds (1000 kg ha^{-1} in 2021 and 1069 kg ha^{-1} in 2022) were produced when crop sown on 20th January (D_2) and was recorded significantly highest among other sowing dates treatment. Although it was found statistically comparable and at par with crop sown on 30th January (D_3) during both experimental year and in addition of crop sown on 09th February (D_4) during second experiment year. The lowest quantity of graded seeds (651 kg ha^{-1} and 664 kg ha^{-1} during 2021 and 2022, respectively) was recorded with early sown crop of 10th January (D_1). This might be due to the lower seed yield obtained in early sown crop.

Effect of spacing

The data recorded on quantity of graded seeds obtained after grading of dhaincha as influenced by different spacing treatment was found significant. The maximum graded seeds of 1042 kg ha^{-1} in 2021 and 1137 kg ha^{-1} in 2022 with year mean of 1090 kg ha^{-1} was obtained when the crop was sown with 30 x 20 cm (S_2) spacing and was found significantly higher than other three spacing variations. The minimum quantity of graded seeds of dhaincha was obtained with crop sown at wider spacing of 45 x 20 cm (S_4) during both experimental year with graded quantity of 676 kg ha^{-1} and 718 kg ha^{-1}, respectively.

Interaction effect

The interaction effect between different sowing dates and spacings on quantity of graded seeds obtained from dhaincha was found significant during both the studied year (Table 5). In general, quantity of graded seeds of dhaincha decreased with early or delays in sowing from 20th January at optimum spacing of 30 x 20 cm. The maximum quantity of graded seeds (1294 kg ha^{-1} and 1430 kg ha^{-1}) during both year of 2021 and 2022, respectively was obtained with crop sown on 20th January (D_2) at optimum row and plant spacing of 30 x 20 cm (S_2) and was found significantly maximum than any other combinations of sowing date and spacing treatments. This was followed by sowing of dhaincha with 30th January (D_3) and 9th February (D_4) with same spacing of 30 x 20 cm (S_2). The lowest graded seed quantity was obtained with early sowing of 10th January (D_1) at wider spacing of 45 x 20 cm (S_4) and was found statistically at par with spacing of 45 x 10 cm (S_3) and 30 x 10 cm (S_1) during both year of experiment.

Germination (%)

Data pertaining to germination percent of dhaincha as influenced by different sowing dates and spacings is tabulated in Table 4. The recorded data indicated that germination percentage differ significantly among the variations caused by sowing dates and spacings, but the interaction effect did not differ significantly.

Effect of sowing date

Germination percentage of dhaincha graded seeds was found significant as influenced by different sowing dates during post rainy season. Numerically maximum germination percentage of dhaincha graded seeds (84.17% and 85.92%) during both consecutive year was recorded with 20th January (D_2) sowing date and it was significantly higher compared to rest other sowing dates. However, it showed statistically at par results with 30th January (D_3) sowing date in 2021 and 30th January (D_3) and 09th February (D_4) sowing dates in 2022. Statistically the lowest germination percentage count of dhaincha graded seeds was recorded with early sown crop on 10th January (D_1) with 75.83% and 78.08% during 2021 and 2022, respectively with year mean of 76.96%.

Effect of spacing

Germination percentage of dhaincha seeds as influenced by spacings was found non-significant during first year of 2021. Although, spacing of 30 x 20 cm (S_2) recorded maximum germination percentage of 82.42% and lowest germination percentage of 79.58% was recorded with spacing of 30 x 10 cm (S_1). During second year (2022), 30 x 20 cm (S_2) spacing had resulted in significantly maximum germination percentage of 84.50% compared to the rest of the other spacing treatments. However, it was statistically comparable and at par with spacing of 45 x 10 cm (S_3) and 45 x 20 cm (S_4). The lowest germination percentage (81.58%) was recorded with crop sown at closer spacing of 30 x 10 cm (S_1). The higher value of germination percentage on above treatments might be due to prevailing weather that supported the various physiological processes to ignite the germination and proper growth of the seedlings. These findings are in conformity with Parlawar *et al.* (2004) [8].

Interaction effect

The interaction effect due to different sowing dates and spacings on germination percentage of dhaincha graded seeds was found non-significant.

Economics

Cost of Cultivation (Rs ha^{-1})

The cost of cultivation per hectare has been worked out and appended with prevailing market price of produce inputs from land preparation upto harvesting and threshing (seed, fertilizer, wage labour cost etc.). On basis of prevailing market price of inputs, fixed cost, variable cost and total cost of cultivation was calculated. Based on the calculations, it was found that treatment of sowing dates of dhaincha is a non-monetary input and has no effect on cost of cultivation. Rs 29,820 ha^{-1} and Rs 30,705 ha^{-1} was calculated for all four

date of sowing treatments of dhaincha during 2021 and 2022, respectively. On the other hand, among different spacing treatment, closer spacing of 30 x 10 cm (S_1) resulted in to maximum cost of cultivation than the other (Rs 31,749 ha^{-1} during 2021 and Rs 32,624 ha^{-1} during 2022). This was due to more requirements of seeds and seed treating materials. The lowest cost of cultivation (Rs 30,464 ha^{-1} in 2021 and Rs 31,349 ha^{-1} in 2022) was calculated in wider spaced sown dhaincha crop of 45 x 20 cm (S_4).

Gross returns (Rs ha^{-1})

The data revealed that gross returns of dhaincha are influenced due to different sowing time as well as different spacings (Table 6). Among different sowing dates of dhaincha, 20th January (D_2) sown dhaincha crop recorded maximum gross returns of Rs 90,460 and 97,048 ha^{-1}, respectively during both the studied year, which was significantly higher than 30th January (D_3) and 09th February (D_4) sown crop. Sowing of 30th January (D_3) recorded year mean gross returns of Rs 82,214 ha$^{-1,}$ while 09th February (D_4) sown dhaincha crop recorded year mean gross returns of Rs 77,855 ha^{-1}. The minimum gross return (Rs. 60,295 ha^{-1} and Rs 62,802 ha^{-1}) were fetched in early sown dhaincha crop of 10th January (D_1).

As far as different spacing treatment was concerned, maximum gross returns of Rs 93,271 and Rs 1,00,549 ha^{-1} was obtained with spacing of 30 x 20 cm (S_2), which was higher than 30 x10 cm (S_1) and 45 x 10 cm (S_3). This was due to higher seed yield ha^{-1} obtained at 30 x 20 cm spacing crop than other spacing treatments. The lowest gross return of Rs 62,719 and Rs 66,181 ha^{-1} of dhaincha crop during both consecutive year, due to different spacing treatment was recorded under wider spacing crop of 45 x 20 cm (S_4).

Net returns (Rs ha^{-1})

The data on net returns as influenced by different sowing dates and spacing of dhaincha are presented in Table 6. The same trend was reflected in net return as found in gross returns. Among different sowing dates of dhaincha, 20th January (D_2) sown dhaincha crop recorded maximum net returns of Rs 60,640 and Rs 66,343 ha^{-1}, respectively during both the studied year, which was higher than 30th January (D_3) and 09th February (D_4) sown crop. Sowing of 30th January (D_3) recorded year mean net returns of Rs 51,951 ha$^{-1,}$ while 09th February (D_4) sown dhaincha crop recorded year mean net returns of Rs 47,592 ha^{-1}. The minimum net return (Rs. 30,475 ha^{-1} and Rs 32,097 ha^{-1}) were fetched in early sown dhaincha crop of 10th January (D_1).

As far as different spacing treatment was concerned, maximum net returns of Rs 62,487 and Rs 68,880 ha^{-1} was obtained with spacing of 30 x 20 cm (S_2), which was higher than 30 x10 cm (S_1) and 45 x 10 cm (S_3). This was due to higher seed and stover yield ha^{-1} obtained at 30 x 20 cm spacing crop than other spacing treatments. The lowest net return of Rs 32,255 and Rs 34,832 ha^{-1} of dhaincha crop during both consecutive year, due to different spacing treatment was recorded under wider spacing crop of 45 x 20 cm (S_4).

Benefit Cost Ratio

Data calculated for benefit cost ratio (B: C ratio) of dhaincha as influenced by different sowing date and spacing revealed that there is a remarkable differences. Among different sowing dates, sowing of dhaincha during 20th January (D_2) recorded higher benefit: cost ratio (3.03 and 3.16) as compared to other sowing dates during 2021 and 2022, respectively, which was followed by 30th January (2.67 and 2.77) and 09th February (2.48 and 2.66) sowing dates. On contrarily, early sowing on 10th January (D_1) recorded the lowest benefit: cost ratio (2.02 and 2.05).

Among different spacing treatments, sowing with spacing 30 x 20 cm (S_2) gave the highest benefit: cost ratio (3.03 and 3.17) among other different spacing treatments. This was followed by 30 x 10 cm (S_1) and 45 x 10 cm (S_3). While, the lowest benefit: cost ratios (2.06 and 2.11) during both the year, were noted with wider spacing of 45 x 20 cm (S_4).

Table 1: Number of seeds pod^{-1}, pod length and test weight of dhaincha as influenced by different sowing time and spacing

Treatment	Number of seeds pod^{-1}			Pod length (cm)			Test weight (g)		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Sowing time (D)									
D_1 - 10th Jan	21.56	22.70	22.13	18.92	19.71	19.31	15.74	16.54	16.14
D_2 - 20th Jan	31.61	32.22	31.91	20.71	21.88	21.30	21.07	21.29	21.18
D_3 - 30th Jan	29.88	29.96	29.92	18.91	20.19	19.55	20.38	20.68	20.53
D_4 - 09th Feb	26.24	27.62	26.93	17.28	18.61	17.95	20.14	20.43	20.29
S.Em+	0.60	0.38	0.45	0.25	0.18	0.21	0.16	0.21	0.18
CD(P=0.05)	2.09	1.31	1.55	0.87	0.62	0.72	0.57	0.71	0.63
Spacing (S)									
S_1 - 30 x 10 cm	21.90	22.76	22.33	15.04	15.71	15.38	17.94	18.33	18.14
S_2 - 30 x 20 cm	26.91	27.67	27.29	18.06	19.28	18.67	18.84	19.19	19.02
S_3 - 45 x 10 cm	29.29	30.34	29.81	20.78	21.99	21.39	20.01	20.54	20.27
S_4 - 45 x 20 cm	31.20	31.73	31.47	21.95	23.42	22.68	20.53	20.88	20.71
S.Em+	0.39	0.40	0.36	0.36	0.38	0.36	0.17	0.17	0.17
CD(P=0.05)	1.13	1.16	1.05	1.05	1.11	1.05	0.49	0.50	0.49

Table 2: Seed yield (kg ha^{-1}) and stover yield (kg ha^{-1}) of dhaincha as influenced by different sowing time and spacing

Treatment	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2021	2022	Mean	2021	2022	Mean
Sowing time (D)						
D_1 - 10th Jan	797	829	813	5006	5302	5154
D_2 - 20th Jan	1191	1276	1233	7878	8587	8232
D_3 - 30th Jan	1043	1112	1077	7282	7882	7582
D_4 - 09th Feb	975	1075	1025	6464	7102	6783
S.Em+	50	55	53	253	279	266
CD(P=0.05)	172	192	182	874	964	919
Spacing (S)						
S_1 - 30 x 10 cm	994	1074	1034	6932	7550	7241
S_2 - 30 x 20 cm	1238	1342	1290	7346	7930	7638
S_3 - 45 x 10 cm	952	1004	978	6597	7138	6868
S_4 - 45 x 20 cm	822	871	847	5754	6253	6003
S.Em+	11	11	11	109	120	114
CD(P=0.05)	31	32	31	319	350	334

Table 3: Interaction effect of sowing time and spacing on seed yield (q ha^{-1}) and stover yield (q ha^{-1}) of dhaincha

Seed yield (kg ha^{-1})												
Treatment	2021				2022				Mean			
	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm
10th Jan	761	831	834	760	834	896	821	766	797	864	828	763
20th Jan	1252	1518	1088	907	1343	1635	1161	965	1297	1577	1124	936
30th Jan	1019	1348	956	848	1077	1444	1018	909	1048	1396	987	878
09th Feb	943	1254	931	773	1043	1392	1018	846	993	1323	975	809
	D x S		S x D		D x S		S x D		D x S		S x D	
S.Em+	20		53		22		64		21		58	
CD	60		179		64		200		61		189	

Stover yield (kg ha^{-1})												
Treatment	2021				2022				Mean			
	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm
10th Jan	5407	5179	5028	4412	5734	5488	5326	4660	5571	5333	5177	4536
20th Jan	8308	8736	7972	6495	9099	9518	8568	7162	8703	9127	8270	6828
30th Jan	7403	8299	7228	6196	8080	8919	7870	6658	7741	8609	7549	6427
09th Feb	6612	7171	6160	5912	7288	7797	6790	6532	6950	7484	6475	6222
	D x S		S x D		D x S		S x D		D x S		S x D	
S.Em+	219		316		222		349		228		334	
CD	638		1031		NS		1135		668		1083	

Table 4: Quantity of graded seeds (kg ha^{-1}) and germination percent of dhaincha as influenced by different sowing time and spacing

Treatment	Quantity of graded seeds(kg ha^{-1})			Germination percent(kg ha^{-1})		
	2021	2022	Mean	2021	2022	Mean
Sowing time (D)						
D_1 - 10th Jan	651	664	658	75.83	78.08	76.96
D_2 - 20th Jan	1000	1069	1035	84.17	85.92	85.04
D_3 - 30th Jan	871	931	901	83.25	85.08	84.17
D_4 - 09th Feb	811	904	857	81.58	84.67	83.13
S.Em+	44	53	48	0.43	0.37	0.37
CD(P=0.05)	152	183	167	1.49	1.29	1.28
Spacing (S)						
S_1 - 30 x 10 cm	824	892	858	79.58	81.58	80.58
S_2 - 30 x 20 cm	1042	1137	1090	82.42	84.50	83.46
S_3 - 45 x 10 cm	790	820	805	81.08	83.50	82.29
S_4 - 45 x 20 cm	676	718	697	81.75	84.17	82.96
S.Em+	10	11	10	0.82	0.68	0.64
CD(P=0.05)	29	31	28	NS	1.99	1.85

Table 5: Interaction effect of sowing time and spacing on quantity of graded seeds (kg ha^{-1}) and undersized seeds (kg ha^{-1}) of dhaincha

Quantity of graded seeds (kg ha^{-1})												
Treatment	2021				2022				Mean			
	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm	30 x 10 cm	30 x 20 cm	45 x 10 cm	45 x 20 cm
10th Jan	602	674	694	632	666	734	674	633	634	704	684	632
20th Jan	1057	1294	920	730	1152	1430	961	795	1104	1362	940	762
30th Jan	856	1144	779	704	917	1244	843	773	887	1194	811	738
09th Feb	781	1056	770	638	888	1199	860	718	835	1127	815	678
	D x S		S x D		D x S		S x D		D x S		S x D	
S.Em+	18		47		21		57		19		52	
CD	53		159		62		190		56		174	

Table 6: Economics of dhaincha as influenced by different sowing time and spacing

Treatment	Cost of cultivation(Rs ha^{-1})			Gross return(Rs ha^{-1})			Net return(Rs ha^{-1})			Benefit: Cost ratio		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Sowing time (D)												
10th Jan	29820	30705	30263	60295	62802	61549	30475	32097	31286	2.02	2.05	2.03
20th Jan	29820	30705	30263	90460	97048	93719	60640	66343	63456	3.03	3.16	3.10
30th Jan	29820	30705	30263	79564	84934	82214	49744	54229	51951	2.67	2.77	2.72
09th Feb	29820	30705	30263	74068	81642	77855	44248	50937	47592	2.48	2.66	2.57
Spacing (S)												
30 x 10 cm	31749	32634	32192	75819	81472	78646	44070	48838	46454	2.39	2.50	2.44
30 x 20 cm	30784	31669	31227	93271	100549	96911	62487	68880	65684	3.03	3.17	3.10
45 x 10 cm	31076	31961	31519	72577	76229	74403	41501	44268	42884	2.34	2.39	2.36
45 x 20 cm	30464	31349	30907	62719	66181	64485	32255	34832	33578	2.06	2.11	2.09

Conclusion

This gives an option to conclude that sowing of dhaincha during post rainy season, 20th of January with spacing of 30 x 20 is an ideal agronomic practice for improving the dhaincha productivity with maximum seed yield, stover yield, quantity of graded seeds, germination percent, gross income, net income and B:C ratio.

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