NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 42, 2025
www.incda-fundulea.ro; doi.org/10.59665/rar4207 First Online: December, 2024. DII 2067-5720 RAR 2025-23

Effect of Sowing Date and Plant Density on Quantitative and Qualitative Yield of Brown Mustard (*Brassica juncea*) Under Saline and Non-Saline Soil Conditions

Hasan Amiri[1], Hossein Ajamnorozi[1], Mohammad Taghi Feyzbakhsh[1,2*], Mohammad Reza Dadashi[1]

[1]Department of Agronomy, Gorgan Branch, Islamic Azad University, Gorgan, Iran

[2]Horticulture and Agronomy Department, Golestan Agricultural and Natural Resources Research and Education Center. Agricultural Research, Education and Extension Organization (AREEO), Gorgan, Iran

[*]Corresponding author. E-mail: feyz_54@yahoo.com

ABSTRACT

To investigate the effects of sowing date and plant density on quantitative and qualitative yield of forage brown mustard (S-83 line), a split-plot experiment based on a randomized complete blocks design with four replicates was carried out in 2015 and 2016. The experiment was done in saline (10 ds/m) and non-saline (2 ds/m) environments in the research farm of Mazraeh Nemooneh (Anbaralum township), Iran. The main factor was the sowing date at five levels (starting from Nov 6, with 15-day intervals), and plant density at three levels (208000, 277000 and 416000) was assigned to subplots. The results showed that the effects of year and sowing date on all traits were significant at p<0.01. Also, the effect of plant density on the number of branches, fresh forage yield, pods per plant and fresh pod weight was significant at p<0.01. Furthermore, the interaction effect of year × environment on plant height, fresh forage yield, pods per plant, dry forage yield, number of auxiliary branches, leaf fiber percentage and phenological traits of brown mustard was significant at p<0.01. The mean comparison showed that late sowing led to an increase in leaf protein and fiber percentage, whereas salinity significantly decreased shoot dry weight, plant height and fresh and dry forage yield. Also, soil salinity not only decreased the protein percentage but lowered forage quality and fresh forage yield by 7000 and 4000 kg/ha in the first and second years, respectively. The highest forage yield was 42593.5 kg/ha and obtained when the plant was sown on Nov 6, and late sowing decreased the yield. Overall, sowing on Nov 6 was optimum and later sowing dates lead to decreased fresh and dry forage yield.

Keywords: fiber, forage yield, plant density, protein, salinity.

INTRODUCTION

Brown mustard (*Brassica Juncea*, Brassicaceae) is an annual herb that grows naturally in the elevated areas of Asia and Africa. The seeds of brown mustard are obtained from various plants of *Brassica* or *Sinapis* genera, as most of them are similar and cross-bred.

Growing population has excessively intensified the pressure on soil and water resources. Despite the fact that more resources are required for increased production of crops, improper management measures have resulted in the secondary salinity in arable lands, leading to the loss of water and land resources (Kafi et al., 2009).

Forage constitutes an essential part of the ruminant feed. Various forages are used in livestock nutrition, including plants of the *Brassica* genus. In near future, soil salinity derived from natural or anthropogenic activities will affect almost half of the global crop cultivation area. This will negatively affect successful crop production, especially in arid and semi-arid areas (Omara and El-Gaafarey, 2018). On the other hand, most crops are unable to grow in saline soil and water. However, there are plants that may be used as forage crops under these conditions (Khan et al., 2009). Brown mustard (*Brassica juncea* L.) is an herbaceous annual in the family Brassicaceae and is considered multi-use crop grown for vegetable oil, leafy greens, spice, and protein meal and is moderately tolerant to salinity (Hooks et al., 2019).

In a study carried out under salinity stress, seed germination, seedling growth, plant

Received 7 September 2024; accepted 18 December 2024.

height (shoot/root ratio), dry matter, branching and pod formation significantly reduced in wild mustard. Also, salinity reduced the biological yield and grain yield of wild mustard by 50 and 70 percent, respectively. The effect of salinity stress varies depending on the species, type and level of stress, which may affect wild mustard growth and yield (Phour and Sindhu, 2020).

Suitable plant density is essential in improving crop yield. At low densities, plants tend to allocate most of their biomass to reproductive structures (Kleunen et al., 2001; Weiner, 2004). Increased density limits the availability of resources such as water, space and nutrients, which leads to decreased biomass and grain yield per plant (Li-chao et al., 2018). On the other hand, increased density results in more inflorescence per unit area. Also, higher density slightly increases grain number (Qun et al., 2020). When two or more plants need a certain factor to grow, and the supply for this factor is lower than its instant demand, yield in canola and mustard is affected by intra-specific competition. It is well established that the environment - i.e. irradiation and CO_2 concentration - can play a crucial role in photosynthesis and consequently, dry matter accumulation and vegetative growth. Hence, plant density can play a great role in the yield of various crops including brown mustard by affecting the two mentioned parameters (Mamun et al., 2014). Accordding to Karydogianni et al. (2022), Black Mustard [*Brassica nigra* (L.) Koch] plant densities higher than 46 plants m^{-2} and under inorganic fertilization, could be successfully used as a novel forage crop in ruminants' diets. They reported that the highest dry matter yield (17.55-18.34 tn ha^{-1}) was observed in high-density plots (76 plants m^{-2}).

Sowing date is among the most important factors affecting phenological growth, source-sink relationships and allocation of assimilate to various parts of a plant (Khalil et al., 2010). According to (Khajepoor, 2011), the purpose of selecting a sowing date is to determine the suitable time to sow a cultivar(s) of a crop, so that the collective environmental factors occurring at that time are suitable for emergence, survival and establishment of the seedling. Furthermore, the plant may face optimal conditions at any growth stage and avoid unsuitable conditions. According to (Askarnejad et al., 2015) the effect of sowing date on plant height, number of auxiliary branches, racemes per plant, grains per raceme, 1000 grain weight, grain yield, biological yield and oil yield of black mustard was significant at $p<0.01$, whereas the effect of density was only significant on the number of auxiliary branches, racemes per plant at $p<0.05$.

In a study, Feyzbakhsh (2010) reported that the yield of forage mustard in the Anbaralum region is 40 tons/ha, so this plant is a suitable alternative for forage production. Forage mustard is sown in autumn and can provide the forage required in early spring, as this season coincides with the depletion of silage in husbandries. On the other hand, this plant can grow in regions with relatively saline water. Also due to the severe limitation in water supply and high water requirement of forage plants such as alfalfa and forage maize, brown mustard may be used in livestock feed, especially for cows. Total digestible minerals are 50-55 percent or higher on average.

According to Feyzbakhsh (2010), harvested forage from brown mustard in the Anbaralum region during two years of the experiment was 38437.5 and 39937.5 kg/ha for the first and second years, respectively, which in both years was superior to other forage crops studied (vetch, lathyrus, forage beet, forage pumpkin and forage sorrel). Thus, this crop was recommended as a new forage plant in Golestan province, Iran. Zanozina and Bushnev (2022) reported that highest productivity (1.11 t/ha) and oil yield (0.44 t/ha) in brown mustard obtained at the beginning of May sowing date with the seeding rate of 1.3 million pcs/ha in Western Ciscaucasia. Plants produce more productive branches (13 pcs/plant) and pods (106 pcs/plant).

The amount of protein stored in the tissues of forage crops is an essential index to estimate forage quality. Forage mustard has a protein content of 12-14 percent (Canada's Saskatchewan Agricultural Knowledge Center, 2008), which is slightly lower than barley.

The importance of mustard is due to being a high-yielding crop as well as its ability to grow under a wide range of environmental conditions. The digestibility of forage mustard is approx. 48%. Since crops are prone to be affected by sowing date and plant density, and lack of sufficient information on the cultivation of forage mustard, the present study was carried out to determine the best sowing date and plant density and their effect on quantity and quality of mustard yield.

MATERIAL AND METHODS

The experiment was carried out in two agricultural years (2015 and 2016) at Anbaralum town (54°38'E, 37°9'N) research station, which is situated at an elevation of -5 m from sea Level in Iran. To measure the soil characteristics of the field, samples were taken from 0-30 cm depths from different points, and physicochemical properties were determined (Table 1).

Table 1. Soil characteristics in saline and non-saline conditions

Soil characteristics	Saline	Non-saline
Depth (cm)	0-30	0-30
Electric conductance (dS/m)	10	2
pH	7.38	7.18
Organic matter (%)	1.10	1.20
Phosphorous (mg/kg)	7.24	8.20
Potassium (mg/kg)	240	460
Sand (%)	14	12
Silt (%)	56	52
Clay (%)	30	36
Texture	Silt-Clay-loam	Silt-Clay-loam

Cultivar characteristics

This cultivar (S-83 line) was provided by Seed and Plant Improvement Institute, Karaj, Iran, and has a stem height of up to 200-250 cm.

Climate conditions

Meteorological data (minimum and maximum temperature and rainfall) were obtained from the nearest weather station (1 km) located in Mazraeh Nemooneh (Anbaralum township) (Table 2).

This experiment was done in saline (10 ds/m) and non-saline (2 ds/m) environments as a split plot based on a randomized complete blocks design with four replicates. The main factor was the sowing date at five levels (starting from Nov 6, with 15-day intervals), and plant density at three levels (208000, 277000 and 416000) was assigned to subplots. The length and width of each plot were 6 and 3 m, respectively. Plant density was maintained using the inter-row spaces of 24, 36 and 48 cm, thus the plots contained 12, 8 and 6 lines, respectively, and the inter-row space was 10 cm for all treatments. The space between the replicates was 2 m. Also, the plots in each replicate had a space of 1 m (non-cultivation) to minimize shading and facilitate farm operations.

The final harvest was done after the elimination of the border effect. Agronomic traits, fresh and dry forage yield, plant height, stem diameter, number of auxiliary branches, pods per plant, and fresh and dry pod weight were measured. To determine the dry matter and measure protein content and raw fiber, a 1-kilogram sample of fresh forage, shoot and leaf from each plot was transferred into an oven for 72 h at 75°C. Then, the samples were sent to the lab and protein and raw fiber were determined. The height of 10 plants from the ground level to the end of the main stem was measured using a long wooden ruler. Also, 10 plants were chosen to measure the number of branches and pods per plant.

Analysis of variance was carried out using the SAS software. Duncan's multiple range test was used for mean comparison at $p<0.05$. All figures were drawn using Microsoft Excel.

Table 2. Rainfall and temperature

Average annual rainfall (mm) (Statistics for 10 years 2005-2015)	355.5	
The amount of precipitation during the growing season (mm)	2015	303
	2016	258.8
Growing season temperature (°C)	Average min	
	2015	8.05
	2016	20.9
	Average max	
	2015	6.3
	2016	17.7
Average annual temperature (°C)	min	18.5
	max	38.6

RESULTS AND DISCUSSION

Analysis of variance for the studied traits

The effect of year on all studied traits (days to flowering and days to harvest, plant height, fresh and dry forage yield, number of branches per plant, pods per plant, pod fresh weight, leaf, stem and pod protein percentage, and leaf and stem fiber percentage) was significant except for pod fiber percentage (Table 3). The effects of the environment (saline and non-saline) and sowing date on all traits were significant. Interaction of year × environment on days to flowering, days to harvest, plant height, number of auxiliary branches, fresh forage yield and leaf fiber percentage was significant (Table 3).

Interaction of environment × sowing date on days to harvest, plant height, number of auxiliary branches, fresh forage yield and fresh pod weight was significant. Effects of plant density and the Interaction of density × sowing date were only significant on the number of auxiliary branches, fresh and dry forage yield, pods per plant and fresh pod weight. Also, the Interaction of density × environment on plant height, and fresh and dry forage yield was significant (Table 3).

Table 3. Variance analysis of investigated traits in fodder mustard during the years 2014 and 2015

S.O.V.	df	Day to flowering	Day to harvest	Bush height	More fodder weight	Dry fodder weight	Number of branches per plant	Leaf protein	Stem protein	Sheath protein	Leaf fibers	Stem fibers	Sheath fibers
year (y)	1	162.45**	120.05**	3593.8**	1074397103**	65261079.1**	86.8**	29.26**	3.74*	16.92**	59.52*	41.29*	1.33^{ns}
p	1	984.97**	61.25**	40485**	1394028969**	85274103.7**	6.1**	7.93*	4.34*	33.1**	121.37**	140.41*	189.27**
y*p	1	123.33**	31.25**	704.5**	103760381**	7737863.5**	0.88*	1.97^{ns}	4.34*	0.99^{ns}	49.60*	7.48^{ns}	32.41^{ns}
r(y*p)	8	0.96	2.47	99.17	930012	668472.7	1.21	40.32	28.26	48.65	324.8	598.99	517.83
a	4	372.7**	8060.23**	8442.1**	680540167**	40290140.7**	12.6**	64.99**	4.22**	39.61**	56.09**	215.39**	82.34**
p*a	4	279.17**	36.09**	964.9**	25229477**	1232183.6**	10.95**	0.86^{ns}	0.25^{ns}	2.04*	0.58^{ns}	6.41^{ns}	4.06^{ns}
y*a	4	58.67**	73.92**	46.7^{ns}	4540556**	357293.6**	0.35^{ns}	6.75*	0.58*	4.23**	9.71^{ns}	18.36^{ns}	3.60^{ns}
y*p*a	4	61.48**	51.07**	36.64^{ns}	6818586**	574236**	0.448*	0.91^{ns}	0.14^{ns}	0.71^{ns}	0.215^{ns}	8.37^{ns}	3.34^{ns}
Error*r(y*p)	32	0.51	1.23	815.22	3435805	197198.1	0.801	5.71	0.55	2.57	5.87	26.38	13.62
b	2	0.52^{ns}	1.51^{ns}	144.5^{ns}	126597685**	7574436.7**	95.4**	1.22^{ns}	0.05^{ns}	0.97^{ns}	1.78^{ns}	15.64^{ns}	1.19^{ns}
a*b	8	1.08^{ns}	0.36^{ns}	33.5^{ns}	3254816**	144768.1**	1.2**	0.11^{ns}	0.11^{ns}	0.15^{ns}	0.12^{ns}	1.17^{ns}	8.63^{ns}
y*b	2	0.82^{ns}	3.81*	308.4*	1664762**	887257.7**	0.47^{ns}	0.16^{ns}	0.4^{ns}	0.19^{ns}	0.18^{ns}	2.28^{ns}	0.59^{ns}
p*b	2	0.21^{ns}	0.32^{ns}	756.3**	189894*	4496.6**	0.55^{ns}	0.035^{ns}	0.06^{ns}	0.04^{ns}	0.23^{ns}	1.46^{ns}	5.15^{ns}
y*p*b	2	0.039^{ns}	2.82^{ns}	85.77^{ns}	6064815**	436443.3**	0.166^{ns}	0.313^{ns}	0.06^{ns}	0.12^{ns}	0.16^{ns}	1.39^{ns}	3.10^{ns}
y*a*b	8	0.35^{ns}	0.29^{ns}	21.96^{ns}	964163*	37081*	0.201^{ns}	0.165^{ns}	0.14^{ns}	0.07^{ns}	0.282^{ns}	2.47^{ns}	4.82^{ns}
p*a*b	8	0.174^{ns}	0.031^{ns}	85.82^{ns}	181928^{ns}	25411.8^{ns}	0.096^{ns}	0.082^{ns}	0.01^{ns}	0.07^{ns}	0.241^{ns}	1.12^{ns}	6.53^{ns}
y*P*a*b	8	0.123^{ns}	0.083^{ns}	59.54^{ns}	191721^{ns}	10004.8^{ns}	0.115^{ns}	0.050^{ns}	0.03^{ns}	0.04^{ns}	0.166^{ns}	1.49^{ns}	2.49^{ns}
Error	80	0.63	1.09	68.8	363490	21550.5	0.19	1.45	0.36	0.34	5.47	27.94	10.62
C.V(%)		4.04	5.14	4.42	10.03	1.63	4.6	10.99	15.05	6.61	11.85	10.83	12.99

**, * and ns are respectively significant at the probability level of 1 and 5% and non-significance.

Table 4. Comparison of the average effect of the year for the investigated traits in fodder mustard in 2014 and 2015

Characteristics year	Day to flowering	Day to harvest	Plant height (cm)	Fresh fodder (kg/ha)	Dry fodder (kg/ha)	Number of branches per plant	Leaf protein (%)	Stem protein (%)	Sheath protein (%)	Leaf fibers (%)	Stem fibers (%)
2014	77.73^{a*}	143.5^{a}	192.05^{a}	37916.43^{a}	6414.26^{a}	10.26^{a}	11.16^{ab}	4.14^{a}	9.34^{a}	20.55^{a}	49.68^{a}
2015	75.83^{b}	141.86^{b}	183.12^{b}	33030.17^{b}	5877.59^{b}	8.87^{b}	11.24^{a}	3.83^{ab}	8.49^{b}	18.91^{b}	47.91^{b}

* In each column and for each treatment, the numbers with the same letters do not have a significant difference at the 5% level.

Table 5. Mean Comparison of interaction effect of environment × year for the investigated traits in fodder mustard in 2014 and 2016

Year	Environment	Day to flowering	Day to harvest	Plant height (cm)	Number of branches per plant	The weight of the fodder (kg/ha)	Dry weight of fodder (kg/ha)	Stem protein (%)	Leaf fibers (%)
First year	salin	76.22^{b}	143.33^{a}	175^{b}	10.01^{b}	34.374.08^{b}	5079.46^{b}	10.01^{b}	20.5^{a}
	non-saline	79.24^{a}	143.66^{a}	209^{a}	10.52^{a}	41458.58^{a}	7755.05^{a}	10.52^{a}	17.8^{b}
Second year	salin	72.67^{b}	140.86^{b}	170^{b}	8.76^{ab}	31006.5^{b}	5333.3^{b}	8.76^{ab}	20.6^{a}
	non-saline	79^{a}	142.86^{a}	196^{a}	8.99^{a}	35053.58^{a}	6310.87^{a}	8.99^{a}	20^{b}

* In each column and for each treatment, the numbers with the same letters do not have a significant difference at the 5% level.

Table 6. Comparison of the average effect of planting date for investigated traits in fodder mustard in 2014 and 2016

Planting date	Day to flowering	Plant height (cm)	Leaf protein (%)	Stem protein (%)	Sheath protein (%)	Leaf fibers (%)	Stem fibers (%)	Sheath fibers (%)
November 15	80.89^{a}	185.23^{c}	12.39^{a}	4.48^{a}	10.28^{a}	18.28^{cd}	45.81^{d}	23.69^{d}
November 30	79.16^{ab}	171.14^{d}	122.22^{ab}	4.13^{ab}	9.59^{ab}	18.89^{c}	47.29^{cd}	23.83^{cd}
December15	76.11^{b}	185.76^{c}	10.71^{b}	3.93^{b}	8.84^{b}	19.65^{b}	48.66^{c}	24.73^{c}
December30	73.05^{e}	206.91^{a}	10.21^{c}	3.76^{bc}	8.14^{bc}	20.39^{ab}	50.09^{b}	25.79^{b}
January15	74.64^{d}	188.89^{b}	9.24^{d}	3.06^{c}	7.71^{c}	21.46^{a}	52.12^{a}	27.33^{a}

* In each column and for each treatment, the numbers with the same letters do not have a significant difference at the 5% level.

Table 7. Mean comparison of interaction effects of environment × planting date on the studied traits in fodder mustard in 2014 and 2015

Environment	Planting date	Day to flowering	Day to harvest	Fresh fodder (kg/ha)	Dry fodder (kg/ha)	Number of branches per plant	Plant height (cm)	Sheath protein(%)
Saline environment	November 15	75.78^{a}	160.94^{a}	38698.99^{a}	6775.35^{a}	10.1^{a}	199.6^{a}	10.85^{a}
	November 30	74.33^{bc}	148.56^{b}	35.922.64^{b}	5906.19^{b}	9.6^{ab}	170.9^{b}	10.29^{ab}
	December15	75.22^{ab}	137.61^{c}	33486.74^{c}	5272.42^{c}	8.9^{b}	167^{c}	9.33^{b}
	December30	74.61^{b}	130.2^{d}	29874.68^{d}	4634.19^{d}	7.8^{c}	165.29^{cb}	8.45^{c}
	January15	72.28^{c}	123.28^{e}	25468.91^{e}	3721.14^{e}	5.5^{d}	150.2^{d}	7.79^{d}
Non-saline environment	November 15	86^{a}	164.33^{a}	42593.35^{a}	7736.42^{a}	**10.5^{a}**	221.3^{a}	9.72^{a}
	November 30	84^{ab}	151.44^{b}	40235.45^{b}	7404.92^{b}	8.9^{bc}	211.5^{b}	8.9^{b}
	December15	77^{b}	140.89^{c}	38633.98^{c}	7039.51^{c}	9.3^{b}	202.3^{c}	8.35^{bc}
	December30	71.5^{c}	136.39^{d}	36375.17^{d}	6819.13^{d}	7.8^{d}	191.7^{d}	7.83^{c}
	January15	77^{b}	123.39^{e}	33443.14^{e}	6164.83^{e}	8^{c}	186.1^{de}	7.62^{c}

* In each column and for each treatment, the numbers with the same letters do not have a significant difference at the 5% level.

Table 8. Comparison of the average interaction effect of planting date × plant density in fodder mustard in 2014 and 2015

Planting date	Plant density (plant/m^2)	Fresh weight of fodder (kg/ha)	Dry weight of fodder (kg/ha)	Number of branches in the plant
November 15	208,000	41782.48^{a}	7580.25^{a}	11.99^{a}
	277,000	40725.9^{b}	7220.93^{b}	10.37^{b}
	416,000	39429.8^{b}	6966.66^{c}	8.55^{c}
November 30	208,000	39192.1^{a}	6758.36^{a}	10.9^{a}
	277,000	38110.5^{b}	6701.99^{ab}	9.7^{b}
	416,000	36934.5^{c}	6407.3^{c}	8.45^{c}
December 15	208,000	37152.4^{a}	6395.59^{a}	11.13^{a}
	277,000	36235.4^{b}	6165.11^{b}	9.95^{b}
	416,000	34793.3^{c}	5907.19^{c}	8.55^{c}
December 30	208,000	34520.6^{a}	5990.4^{a}	10^{a}
	277,000	33205.6^{b}	5757.65^{ab}	9.27^{ab}
	416,000	31648.1^{b}	5431.93^{b}	8.32^{b}
January 15	208,000	31512.8^{a}	5306.36^{a}	9.96^{a}
	277,000	29949.7^{a}	5045.63^{b}	8.78^{b}
	416,000	26905.5^{c}	4476.97^{c}	7.51^{c}

* In each column and for each treatment, the numbers with the same letters do not have a significant difference at the 5% level.

Table 9. Mean comparison of interaction effects of environment × plant density on the investigated traits in fodder mustard in 2014 and 2015

Environment	Plant density	Bush height (cm)	Fresh weight of fodder (kg/ha)	Dry weight of fodder (kg/ha)
Saline environment	208,000	175.17[a]	34088.07[a]	5600.57[a]
	277,000	169.88[c]	32888.19[b]	5284.91[b]
	416,000	172.72[b]	31094.91[c]	4900.17[c]
Non-saline environment	208,000	197.06[c]	39576.21[a]	7251.42[a]
	277,000	205[ab]	38402.68[b]	7071.61[b]
	416,000	205.69[a]	36789.76[c]	6775.86[c]

* In each column and for each treatment, the numbers with the same letters do not have a significant difference at the 5% level.

Days to flowering and days to harvest

In both ears, soil salinity led to a decrease in days to flowering and days to harvest. Flowering occurred three and seven days earlier under salinity in the first and second year, respectively, whereas days to harvest were shortened by two days only in the second year (Table 5). The shortest days to flowering and days to harvest were 72.67 and 140.86 days and occurred under salinity stress in the second year, whereas the highest values for these traits were 79.24 and 143.66 days under non-saline conditions (Table 5). The longest days to flowering (86 days) and days to harvest (164 days) were associated with the non-saline environment and Nov 6, and the lowest values were 71.5 and 123.28 days, which occurred when the plants were sown on Dec 21 and non-saline conditions, respectively (Table 7). The results showed that plant phenology is affected by environmental and climatic conditions. Also, salinity led to faster completion of the growing period and earlier harvest of mustard. In fact, most plants shorten their growing period under stress to avoid adverse conditions. On the other hand, stresses are among the growth-limiting factors in most plants which lead to a decrease in growth, photosynthesis and phenology and thus, the plant fails to exploit the growing period optimally. The lowest days to flowering and days to harvest were 76.22 and 140.86 in the second year and salinity treatment, and the highest values were 79.24 and 143.66 which occurred under non-saline conditions, respectively (Table 5). Late sowing led to a decrease in days to flowering and days to harvest (Table 6), so the lowest days to flowering and days to harvest were obtained when mustard was sown on Dec 21 and Jan 5 with 73 and 74.64 days and 133.3 and 123.33 days, respectively (Table 6). However, these values in early sowing treatments were 80.89 and 162.63 days (Table 6). In other words, late-sown forage mustard plants faced adverse temperatures and day length earlier and were unable to exploit the growing period optimally, so they flowered and were harvested earlier. Kumar and Yadav (2022) also reported that delayed sowing date led to early flowering. They stated that in timely sowing date the maximum days to 50% flowering in a 2-year-experiment were 67.95 and 68.55, but in late sowing date were 60.85 and 61.23 respectively.

Regarding the interaction of environment × sowing date, the lowest days to flowering and days to harvest were 71.5 days on Dec 21 and non-saline, and 123.2 days on Jan 6 and saline environments, respectively (Table 7). The highest values for these traits were 86 and 164.3 days and were obtained when sown on Nov 6 in the non-saline environment (Table 7). Regression analysis for days to harvest against the sowing days showed that per each day of delay in sowing, days to harvest decreased by 0.62 and 0.64 days in saline and non-saline environments, respectively (Figure 1). Howlader et al. (2023) indicated that in the coastal areas of southern Bangladesh, the sowing of mustard must be completed within the third week of November and improved varieties having both salinity and temperature stress tolerant can greatly help to boost yield. They reported that crop growth rate, as well as crop duration of mustard varieties, decreased with the delayed sowing.

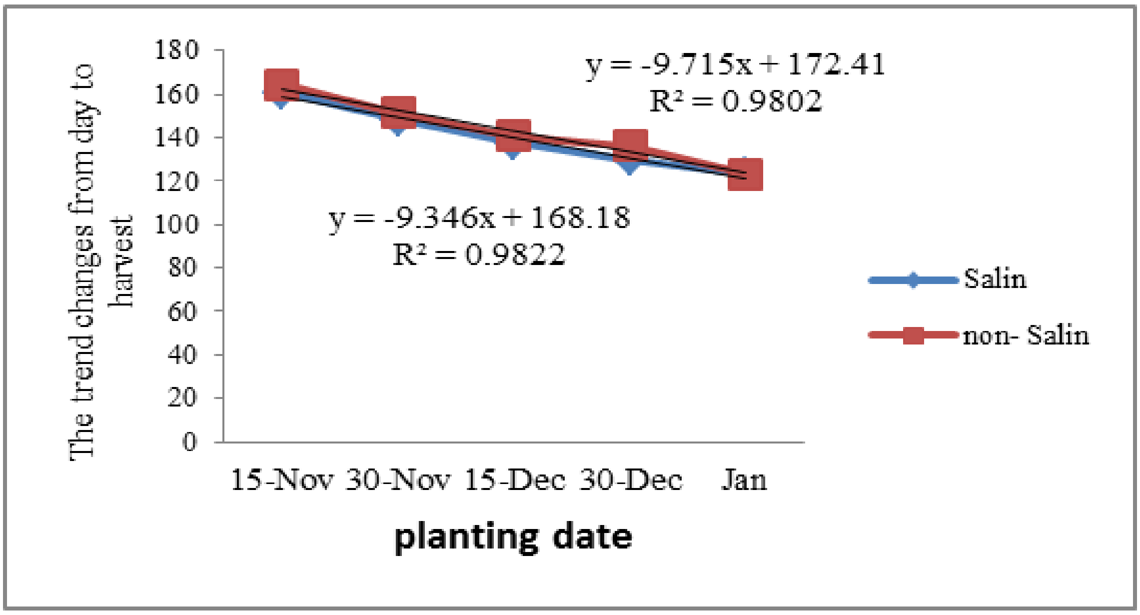

Figure 1. Changes in the days to harvest as affected by the delay in sowing in saline and non-saline environments

Plant height

The greatest plant height (209 cm) was obtained in the first year and non-saline environment (Table 5). In both years, plant height in the saline environment was lesser than that of the non-saline treatment. Plant growth depends on the climatic (temperature and moisture) conditions during the growth period as well as the growth environment, especially soil salinity. Salinity is a growth-limiting factor in plants that negatively affects plant growth and yield. Thus, soil salinity led to decreased forage mustard growth and plant height.

The greatest (206.9 cm) and least (171.1 cm) plant height was obtained when mustard was sown on Nov 6 and Nov 21, respectively (Table 6). Plant height was greater in earlier sowing dates, which is due to the longer time for the plant to exploit the growing season. Also, plants sown early and on time are exposed to the optimal temperature, moisture and day length for a longer time. Also, plant sown with a density of 416000 plants/ha in the non-saline environment were taller (205.7 cm) (Table 9). In other words, plant height increased by 8 cm in the non-saline environment as density increased from 208000 to 416000 plants/ha. Plant height increases at high densities due to the lack of auxin photo-degradation as a result of shading. Similar results have been reported in forage maize by (Feyzbakhsh, 2010) According to our results, plant height at all densities was greater under non-saline conditions. Various studies have shown that increased plant density leads to greater plant height. Moadab Shabestari and Mojtahedi (1990) reported that increased plant height due to higher density is related to etiolation and increased biosynthesis of auxin under shading conditions, which is a strategy to increase crop yield and biomass. Patel et al. (2022) reported the higher plant height with close spacing under transplanted brown mustard. Plant height at 30 and 60 DAT (94 and 180 cm), leaf area index at 30 and 60 DAT (0.87 and 2.03) of transplanted mustard were significantly higher with spacing of 45 cm × 30 cm.

Fresh forage weight

The highest fresh forage weight (41458 kg/ha) was obtained in the first year in the non-saline environment (Table 5), and under both saline and non-saline conditions, this trait was higher in the first year. The lowest value for this trait was 31006 kg/ha and was associated with the saline environment in the second year (Table 5). Salinity as a stress-inducing factor led to diminished growth and yield in forage mustard, so that salinity decreased the fresh forage yield by 7000 and

4000 kg/ha in the first and second years, respectively (Table 5).

Sowing on Nov 6 in the non-saline environment led to the highest fresh forage weight (42593.3 kg/ha), whereas the lowest value was related to Jan 5 in the saline environment (Table 7). In both saline and non-saline environments, the highest yield was obtained when mustard was sown at earlier dates, and delay led to decreased yields (Table 7). Numerous studies show that in some regions, later sowing dates lead to lower yields. Similar results have been reported by (Hashemi Dezfoli at el., 2000) and (Mokhtarpoor, 2001) on forage maize. Hooks et al. (2019) reported that salinity stress caused reductions in leaf area and fresh and dry biomass that averaged 63, 65 and 65 percent relative to the control, respectively.

The highest (41782.8 kg/ha) and lowest (26905.5 kg/ha) fresh forage weights were observed in 208000 plants/ha when sown at Nov 6 and Jan 5, respectively (Table 8). Also, increased plant density in all sowing date treatments led to significantly lower fresh forage weights. At high densities, competition for light, photosynthetically active radiation and nutrients was more intense and thus, plant height increased (Feyzbakhsh, 2010). Also, late sowing led to decreased fresh forage weights at all densities. However, the declivity rate was greater at higher densities (Figure 2), so that at 416000 plants/ha, the highest slope of decrease in the fresh forage weight was observed in response to late sowing.

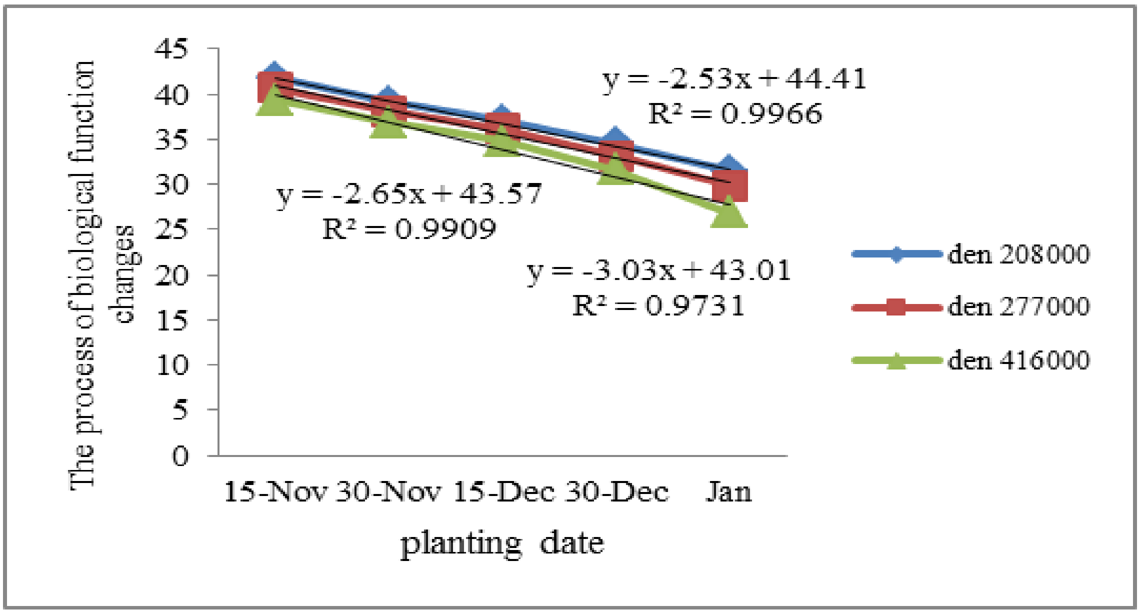

Figure 2. Changes in the fresh forage weight of brown mustard against the sowing date at different densities

The results showed that there was a strong negative relationship between the sowing date and fresh forage weight (under saline and non-saline conditions). The regression relationship between the sowing date and fresh forage weight in the non-saline environment showed that each day of delay in sowing decreased the yield by 148 kg/ha. Also, this decrease was more intense under saline conditions, so that fresh forage weight decreased by 217 kg/ha with per each day of delay in sowing (Figure 8). These results are in accordance with numerous observations.

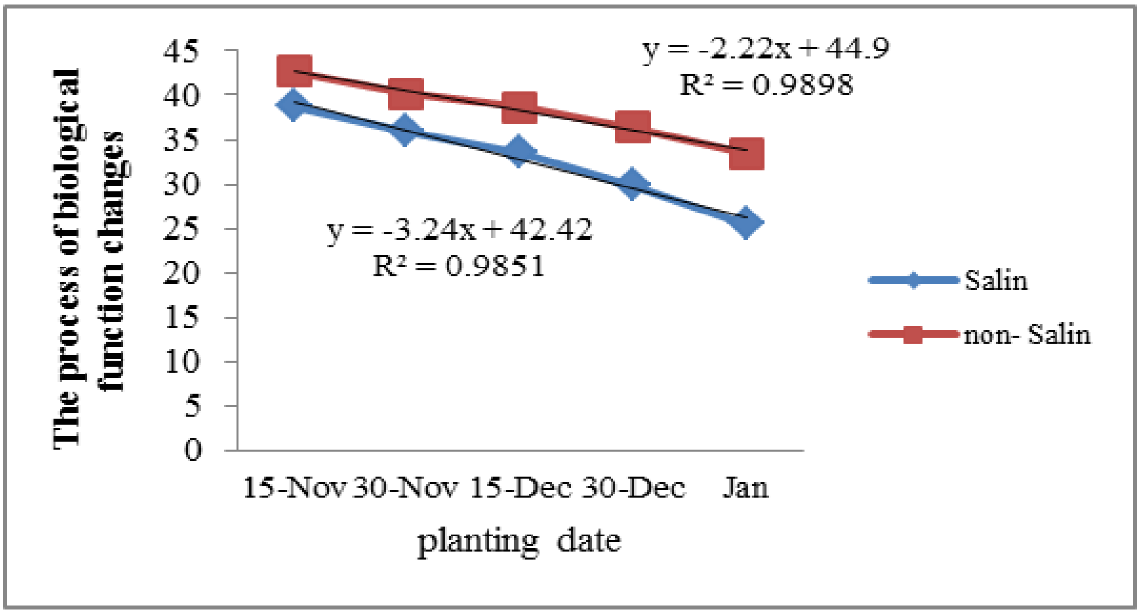

Figure 3. Changes in the fresh forage weight of brown mustard against the sowing dates in saline and non-saline environments

Dry forage weight

The highest dry forage weight was observed when mustard was sown on Nov 6 in the non-saline environment (7755 kg/ha), and the lowest value was 5079.4 kg/ha, which was related to Jan 5 and saline environment (Table 5). Keshta et al. (1999) reported a reduction in canola dry weight under salinity stress. Dry forage weight in the non-saline environment was higher than that of the saline environment at all densities (32.4%). The lowest value for this trait was observed in the saline environment at 416000 plants/ha density with 4900.17 kg/ha (Table 9). Salt stress significantly decreased leaf area and dry matter of brown mustard (Majid et al., 2021).

Comparison of means for the interaction of environment × density showed that at all densities, the dry forage weight of plants sown on Nov 6, Nov 21, Dec 5 and Dec 21 was more than that of Jan 5 (Table 8). In fact, delayed sowing at all densities led to reduced dry forage weight (Table 8), so that at all densities, Jan 5 sowing date had the lowest value for this trait. Dry matter yield of black mustard presented the highest values at the high-plant density of 76 plants m^{-2} (30 cm row spacing) with a 2-year average value being 17.98% higher as compared to the low-density of 46 plants m^{-2} (45 cm row spacing) (Karydogianni et al., 2022).

Number of branches per plant

The highest (10.5) number of branches was obtained in the first year and non-saline environment, and the lowest (8.7) was related to the second year and saline conditions. Nonetheless, the number of branches in the first year was more than that of the second year in both saline and non-saline environments, which may be attributed to the climatic conditions including rainfall and temperature. Also, in both years, the number of branches in the saline environment was lower, which is due to the limited growth under salt stress, which leads to reduced growth and shoot and leaf production in plants.

The comparison of means showed that the highest number of branched per plant (10.5) was obtained when mustard was sown on Nov 6 in the non-saline environment. Also, in all sowing date treatments, the number of branches per plant in the non-saline environment was higher. The lowest value for this trait was 5.5 and associated with Jan 5 and saline environment (Table 7). Enferad at el. (2004) and Arzanesh at el. (2012) also reported a significant reduction in dry matter yield of canola under salt stress. The highest number of branches was obtained when mustard was sown early regardless of the environment. Sharief and Keshta (2006) attributed the reduction in plant height and the number of branches in the canola cultivar to sowing later than early November, which results in a shorter growing period. Singh and Bindra (2020) stated that Brown sarson plants (*Brassica campestris*) had more branches in lower densities so that primary and secondary branches per plant, were found to be significantly higher at 25 plants/m^2 compared to 25 plants/m^2.

Leaf protein and fiber percentage

Leaf protein percentages in both years were statistically similar. The highest value was obtained in the second year with 11.24% and the lowest in the first year with 11.16% (Table 4). Also, the highest percentage of leaf fiber was recorded in the first year with 20.55%, whereas the lowest value was 18.91 and was obtained in the second year (Table 4). Comparison of means for the interaction of environment × year showed that the highest leaf fiber percentage was 20.6% in the second year and saline environment, and the lowest value was 17.8% which was obtained in the first year and non-saline conditions (Table 5).

The protein percentage of leaves for mustard plants sown on Nov 6 was higher than other sowing dates (12.39%) and the lowest value was observed in Jan 5 treatment (9.24%) (Table 6). In contrast, the highest leaf fiber percentage was recorded in Jan 5 treatment with 21.46%, whereas the lowest value was related to mustard plants sown on Nov 6 with 18.28% (Table 6). Thus, the delay in sowing from Nov 6 to Jan 5 led to a 3.18% increase in leaf fiber, which may due to the lower rainfall level in the second year and higher soil salinity. Also, variables that lower the forage nutritional quality (e.g. fiber) increase over time, which is in accordance with our results. In other words, higher temperatures increase the level of lignification, i.e. increased fiber content. In the present study, increased salinity led to decreased raw protein. According to a report, delayed sowing led to a significant increase in the fiber content of forage maize (Salama, 2019). Also, according to our results, density significantly affected the raw fiber content. Increased lignin content due to increased plant density has been reported for black wheat (Wang et al., 2015) and maize (Shi et al., 2016). Tripathi et al. (2021) stated that Protein content of mustard was not influenced significantly due to dates of sowing and varieties. Although concerning the plant density effect Karydogianni et al. (2022) reported that the values of Crude Protein content in low-density plots were higher than in high-density plots. Mahfouz et al. (2020) stated that planting date was significantly affected both of forage quality indices including protein and fiber contents of clitoria plants. The most protein content was observed with late planting while early planting recorded the highest fiber content.

Stem protein and fiber percentage

The protein and fiber percentage of the stem in the first year was higher than that of the second year. The highest value for protein and fiber was obtained in the first year with 4.14 and 49.68%, and the lowest values were obtained in the second year with 3.83 and 47.91%, respectively (Table 4). Results of the environment × year interaction for stem protein showed that the highest value was obtained in the first year and non-saline environment with 10.52% and the lowest in the second year and saline conditions with 8.76 (Table 5). Also, the highest fiber and protein in stems were obtained in Nov 6 treatment with 4.48 and Jan 5 treatment with 52.12%. The lowest values for these traits were 3.06% in Jan 5 treatment and 45.81% in Nov 6 treatment (Table 6).

Pod protein and fiber percentage

According to the results, the highest pod protein percentage was obtained in the first year with 9.34% and the lowest value was 8.49%, which was obtained in the second year (Table 4). Also, the highest protein percentage in pods was 9.22% and obtained in the non-saline environment, and the lowest value was 8.6% in saline conditions. The highest (24.99) and lowest (20.16%) pod fiber percentage was also obtained in saline and non-saline environments, respectively. Verma et al. (2023) reported that salt stress reduced the levels of protein in brown mustard.

Sowing on Nov 6 led to the highest pod protein with 10.28%, and the lowest value was obtained for mustard plants sown on Jan 5 with 7.71% (Table 5). In contrast, plants sown on Jan 5 and Nov 6 had the highest (27.33%) and lowest (23.69%) pod fiber percentage, respectively (Table 6). Kumar and Yadav (2022) also reported that the highest pot protein content (16.92%) have been record in the timely sowing date in India (15^{th} Nov) and the lowest amount of protein content (15.81%) were observed in late sowing date (30^{th} Nov). Also, delayed sowing led to a decreased fiber content in mustard. Also, raw protein content decreased with increasing salinity.

CONCLUSIONS

Salt stress led to a decrease in plant height, fresh and dry forage weight, number of auxiliary branches, days to flowering and harvest and eventually, forage yield of brown mustard. In fact, salinity affected the traits that determine photosynthesis and therefore, decreased fresh and dry forage weight, plant height, branches per plant and yield. In case of a delayed sowing date (Jan 5) plant density may be increased to up to 277000 plants/ha to maximize fresh forage yield. Also, in terms of fresh forage yield, no significant difference was observed between sowing on Nov 6 and Nov 21 under non-saline conditions. Overall, early sowing (Nov 6) and 208000 plants/ha density is recommended in Anbaralum and regions with similar conditions from Iran.

REFERENCES

Agriculture Knowledge Center, Saskatchewan Agriculture, 2008. *Brassica Crops for Hay and Silage (Canola and Mustard).* Available from: http://www.Agriculture.Gov.Sk.Ca.

Arzanesh, M.H., Baniaghil, N., Qorbanli, M.L., Shahbazi, M., 2012. *The effect of plant growth promoting bacteria on growth parameters and the concentration of low consumption elements in two rapeseed cultivars under salt stress.* Journal of Soil Management and Sustainable Production, 2(2): 153-163. (In Persian)

Askarnejad, M.R., Zareai, G., Zareazadeh, A., 2015. *Investigating the effect of planting date and plant density on yield and yield components of black mustard in Abar Kouh weather conditions.* Crop Production, 8(3): 183-198.

Enferad, A., Poustini, K., Majnoun-Hosseini, N., Khajeh-Ahmad-Attari, A.A., 2004. *Physiological responses of rapeseed (Brassica napus L.) varieties to salinity stress in vegetative growth phase*. Journal of Science and Technology of Agriculture and Natural Resources, 7(4): 103-113.

Fyzebakhsh, M.T., 2010. *Preliminary assessment of new forage plants in Golestan Province*. The final report of the Centre Agricultural Research and Natural Resources of Golestan. (In Persian)

Hashemi Dezfoli, S.A., Alemi Sayid, K.H., Syadat, A., Komili, M., 2000. *The effect of planting date on the yield potential of two varieties of sweet corn in the climatic conditions of Khuzestan.* Iranian Journal of Agricultural Sciences, 32(4): 681-689. (In Persian)

Hooks, T., Niu, G., Ganjegunte, G., 2019. *Seedling emergence and seedling growth of mustard and rapeseed genotypes under salt stress*. Agrosystems, Geosciences & Environment, 2(1): 1-8.

Howlader, M.M., Alam, M.J., Gaber, A., Ahmed, S., Hossain, A., 2023. *Sowing date-induced salinity stress impacts the performance of mustard genotypes grown in the coastal saline areas of Bangladesh*. Arabian Journal of Geosciences, 16(3): 202.

Kafi, M., Bor zoee, A., Salehi, M., Kamandi, A., Masoumi, A., Nabati, J., 2009. *Physiology of environmental stresses in plants*. Jahad Daneshgahi Mashhad Press. (In Persian)

Karydogianni, S., Roussis, I., Mavroeidis, A., Kakabouki, I., Tigka, E., Beslemes, D., Stavropoulos, P., Katsenios, N., Tsiplakou, E., Bilalis, D., 2022. *The Influence of Fertilization and Plant Density on the Dry Matter Yield and Quality of Black Mustard [Brassica nigra (L.) Koch]: An Alternative Forage Crop.* Plants, 11(20): 2683.

Keshta. M.M., Hammad, K.M., Sorour, W.A.I., 1999. *New Horizons for an Old Crop*. In Proceedings of the 10^{th} International Rapeseed Congress. Canbera, Australia.

Sharief, A.E., and Keshta, M.M., 2006. *Influence of sowing date and plant density on growth and yield of canola (Brassica napus, L) under salt affected soils in Egypts*. Scientific Journal of King Faisal University (Basic and Applied Sciences), 3(1): 65-78.

Khajehpoor, M.R., 2011. *Principal and Fundamental Agronomy (3ed).* Isfahan University of Technology Press.

Khalil, S.K., Wahab, A., Rehman, A., Muhammad, F., Wahab, S., Khan, A.Z., Zubair, M., Kalan Shah, M., Khalil, I.H., Amin, R., 2010. *Density and planting date influence phonological development assimilate partitioning and dry* *matter production of faba bean*. Pakistan Journal of Botany, 42: 3831-3838.

Khan, M.A., Ansari, R., Ali, H., Gul, B., Nielsen, B.L., 2009. *Panicum turgidum, a potentially sustainable cattle feed alternative to maize for saline areas*. Agriculture Ecosystems and Environment, 129: 542-546.

Kleunen, M.V., Fischer, M., Schmid, B., 2001. *Effects of intraspecific competition on size variation and reproductive allocation in a clonal plant*. Oikos, 94: 515-524. https://doi.org/10.1034/j.1600-0706.2001.940313.x

Kumar, P., and Yadav, A.S., 2022. *To study the effect of different sowing date and sea weed extract on production and productivity of Indian mustard (Brassica juncea L.).* The Pharma Innovation Journal, 11(7): 1688-1692.

Li-chao, Z., Rui-zhi, X., Bo, M., Shao-kun, L., Da-ling, M., 2018. *Evaluation and analysis of intraspecific competition in maize: A case study on plant density experiment*. Journal of Integrative Agriculture, 17(10): 2235-2244.

Mahfouz, H., Megawer, E.A., Maher, A., Shaaban, A., 2020. *Integrated effect of planting dates and irrigation regimes on morpho-physiological response, forage yield and quality, and water use efficiency of clitoria (Clitoria ternatea L.) in arid region.* Archives of Agronomy and Soil Science, 66(2): 152-167.

Majid, A., Rather, B.A., Masood, A., Sehar, Z., Anjum, N.A., Khan, N.A., 2021. *Abscisic acid in coordination with nitrogen alleviates salinity-inhibited photosynthetic potential in mustard by improving proline accumulation and antioxidant activity*. Stresses, 1(3): 162-180.

Mamun, F., Ali, M.H., Chowdhury, I.F., Hasanuzzaman, M., Matin, M.A., 2014. *Performance of Rapeseed and Mustard Varieties Grown under Different Plant Density*. Scientia Agriculturae, 8(2): 70-75.

Moadab Shabestari, M., and Mojtahedi, M., 1990. *Crop Physiology*. Academic Publishing Centre, Tehran. (In Persian)

Mokhtarpoor, H., 2001. *The effect of planting date and plant density on yield and fodder of sweet corn*. Agricultural Research Center of Golestan Province, Science, 18: 218-227. (In Persian)

Omara, A.E., and El-Gaafarey, T., 2018. *Alleviation of Salinity Stress Effects in Forage Cowpea (Vigna unguiculata L.) by Bradyrhizobium sp. Inoculation*. Microbiology Research Journal International, 23(3): 1-16.

Patel, M., Jat, A.L., Malav, J.K., 2022. *Growth and yield response of transplanted mustard (Brassica juncea L.) under different planting schedule in north Gujarat agroclimatic region*. Journal of Oilseed Brassica, 13(1): 37-40.

Phour, M., and Sindhu, S.S., 2020. *Amelioration of salinity stress and growth stimulation of mustard (Brassica juncea L.) by salt-tolerant Pseudomonas species*. Applied Soil Ecology, 149: 103518.

Qun, H., Wei-qin, J., Shi, Q., Zhi-peng, X., Yajie, H., Bao-wei, G., Guodong, G., Hui, G., Hong-cheng, Z., Hai-yan, W., 2020. *Effect of wide-narrow row arrangement in mechanical pot-seedling transplanting and plant density on yield formation and grain quality of japonica rice*. Journal of Integrative Agriculture, 19(5): 1197-1214.

Salama, H.S.A., 2019. *Yield and nutritive value of maize (Zea mays L.) forage as affected by plant density, sowing date and age at harvest*. Italian Journal of Agronomy, 14: 1383.

Shi, D.Y., Li, Y.H., Zhang, J.W., Liu, P., Zhao, B., Dong, S.T., 2016. *Effects of plant density and nitrogen rate on lodging-related stalk traits of summer maize*. Plant, Soil and Environment, 62: 299-306.

Singh, G., and Bindra, A.K., 2020. *Effect of planting density on brown sarson (Brassica campestris var. brown sarson) under different levels of nitrogen and phosphorus in mid-hills of Himachal Pradesh*. Journal of Pharmacognosy and Phytochemistry, 9(5): 621-627.

Tripathi, K.B.M., Gaur, T., Pandey, L., Singh, A., Tiwari, A., Prakash, V., Singh Rathore, U., Singh, R.K., 2021. *Effect of Sowing Dates on Growth and Yield of Indian Mustard (Brassica juncea L.).* International Journal of Current Microbiology and Applied Sciences, 10(01): 3046-3057.

Verma, T., Bhardwaj, S., Raza, A., Djalovic, I., Prasad, P.V., Kapoor, D., 2023. *Mitigation of salt stress in Indian mustard (Brassica juncea L.) by the application of triacontanol and hydrogen sulfide*. Plant Signaling & Behavior, 18(1): 2189371.

Wang, C., Ruan, R.W., Yuan, X.H., Hu, D., Yang, H., Li, Y., Yi, Z.L., 2015. *Effects of nitrogen fertilizer and planting density on the lignin synthesis in the culm in relation to lodging resistance of buckwheat*. Plant Production Science, 18(2): 218-227.

Weiner, J., 2004. *Allocation, plasticity and allometry in plants.* Perspectives in Plant Ecology, Evolution and Systematics, 6: 207-215. https://doi.org/10.1078/1433-8319-00083

Zanozina, O.D., and Bushnev, A.S., 2022. *Formation of yield structure and productivity of spring mustard at different sowing dates*. In: AIP Conference Proceedings, 2767: 020023.