

INTER AND INTRA ROW SPACING EFFECTS ON GROWTH, SEED YIELD AND OIL CONTENTS OF WHITE MUSTARD (*Sinapis alba* L.) UNDER RAINFED CONDITIONS

Muhammad Arif^{1,*}, Muhammad Asif Shehzad² and Salman Mushtaq³

¹Department of Agronomy, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan;

²Department of Agronomy, University of Agriculture, Faisalabad, Pakistan;

³Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan

*Corresponding author's e.mail: jamarif@gmail.com

A field experiment was conducted to evaluate the effect of different plant densities on growth and yield of white mustard during Rabi 2008-09 under rain fed conditions. Three plant spacing (5, 10 and 15cm) and three row spacing (10, 20 and 30cm) were applied during the course of study. Results indicated that plant density has significant effects on growth, seed yield and oil contents of white mustard. Number of pods per plant (2002), number of seeds per pod (4.67), 1000 seed weight (5.02 g), oil contents (32.21 %) and fatty acids except linoleic acid significantly increased by increasing plant spacing due to less competition among plants for moisture, light and nutrients. The maximum plant height (148.9 cm) was with 10 × 20 cm spacing. Maximum seed yield (2046 kg ha⁻¹) was recorded for row spacing 15cm where plants were spaced 10cm within rows. At higher plant density, the overall seed yield of white mustard increased with increasing number of pods per plant. Thus, it is concluded that white mustard should be grown at 150 cm grids for higher yield output.

Keywords: White mustard, plant spacing, inter row spacing, intra row spacing, oil contents

INTRODUCTION

White mustard (*Sinapis alba* L.) is a new emerging oilseed crop belongs to Brassicaceae family. It shows considerable promise as an alternative oilseed crop for dry temperate climates and possesses many beneficial characteristics such as pest resistance and a short growing season (Bodnaryk and Lamb, 1991). It has superior heat and drought tolerance compared to rapeseed (*Brassica napus*) or canola (*Brassica rapa*). Seed pods of white mustard are highly shatter-resistant allowing direct combining of the crop. In crop weed competition studies it has been shown that one wild oat plant was as competitive as four canola plants whereas one white mustard plant was more competitive than two wild oat plants (Duke, 1978).

In Pakistan, farm production is dominated by five major crops, i.e. wheat, rice, cotton, sugarcane and maize whereas oilseeds find relatively low priority in our farming system. This situation leads to an acute shortage of edible oil. A quantity of 1.7 million tons edible oil which amounted to Rs. US\$ 1.65 billions has been imported. The local production is estimated at 0.696 million tons. The oilseed sector, due to ever increasing consumption of edible oil, has attained critical importance to the economy of Pakistan. Steadily increasing demand, meager and fluctuating domestic production base and every increasing import are the salient features of Pakistan's current edible oil situation (Govt. of Pakistan, 2009-10).

The optimum per acre plant population is pre-requisite for higher yield of white mustard like other crops. It enables the plant to utilize land, light and other input resources uniformly and efficiently. Increasing plant population per unit area beyond a certain limit results in competition among the plants for sunlight, nutrients, moisture etc. and may cause severe lodging. So it is imperative to develop such a spacing pattern which may help avoiding excessive crowding and thereby enabling the plants to utilize these resources more effectively and efficiently towards increased production. Plant density is one of the most important cultural practices determining grain yield, as well as other important agronomic attributes of this crop (Sangoi, 2000; Ahmad et al., 2010). Linear increase in grain yield has been reported with increase in plant density until other production factors become limiting (Norsworthy and Emerson, 2005). Similarly, Beg *et al.* (2007) found that the narrow row spacing (20 cm) coupled with low plant spacing resulting in high plant populations of about 100000 plants ha⁻¹ can provide an economical yield under rain-fed conditions. While, low density population produce more branches that carry fertile pods, thus prolonging the seed development phase. Plants grown at high densities are often more susceptible to lodging and increased disease incidence without the benefit of any yield increase, but the presence of fewer pod-bearing branches should produce more synchronous pod and seed development and resulted in more uniform seed maturation, improved harvest ability and

possibly lower seed glucosinolate and higher oil contents (Leach *et al.*, 1999; Abu-Darwish *et al.*, 2011).

The effect of plant spacing on growth, seed yield and chemical constituents of white mustard has not been intensively investigated. Being a minor crop most of the farmers and even researchers are not aware of its basic agronomy and growing requirements. Keeping in view the potential of white mustard and problem being faced by the farmers to grow other oilseed crops, the present study was planned to find out the optimum plant population for obtaining maximum seed yield of white mustard.

MATERIALS AND METHODS

To evaluate the effect of different plant densities on growth and yield of white mustard, a field experiment was carried out at Koont Research Farm, Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi during Rabi 2008-09 under rainfed conditions. The trial was laid out in Randomized Complete Block Design (RCBD) with three replicates. Prior to sowing, land was left fallow during summer and ploughed with the help of cultivator at the end of rainy season. At the time of last ploughing recommended dose of NPK was incorporated into the soil. The crop was sown on 22nd October, 2008 by pora method. Two seeds per hill were sown and later thinned to one plant per hill. Thinning was done at 4-6 leaves stage. Other agronomic operations were kept constant for all the treatments for uniform growth. The total rainfall at the experimental site during the whole growing period was 283.5 mm. Seasonal rainfall and the prevailing temperature during crop growth period are described in Table 1.

The experiment consisted of 3 row spacing and 3 plant spacing. Treatment combinations; T₁ = 5 × 10 cm, T₂ = 5 × 20 cm, T₃ = 5 × 30 cm, T₄ = 10 × 10 cm, T₅ = 10 × 20 cm, T₆ = 10 × 30 cm, T₇ = 15 × 10 cm, T₈ = 15 × 20 cm, T₉ = 15 × 30 cm were used during the whole growing season.

At final harvest, the central three rows from each plot were harvested to record observations on yield and yield attributes. Observations like plant height, number of pods per plant, number of seeds per pod, 1000-seed weight, grain

yield per hectare; percentage oil content and fatty acid profile were recorded using standard procedures. The data collected were subjected to analysis of variance technique and the treatments' means were compared by using Duncan's New Multiple Range (DMR) test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Plant height (cm): The final plant height reflects the growth behavior of a crop, besides genetic characteristics, soil nutrients status and environmental conditions under which it is grown. Planting geometry of a crop plays a vital role in determining the height of the plants. The results presented in the Table 2 indicate that various plant populations had statistically significant effect on plant height of white mustard. The maximum plant height (148.9 cm) was attained by the plants in T₅ (10 × 20 cm) which was statistically at par with T₆ (10 × 30 cm) and T₉ (15 × 30 cm) but differed significantly from rest of the treatments. The minimum plant height (132.4 cm) was observed in T₁ (5 × 10 cm). These results are in agreement with the findings of Oad *et al.* (2001) who observed that taller plants were achieved in the plots where crop was planted in rows of 60 cm apart followed by 45cm and 30cm row spacing.

Number of pods per plant: Results pertaining to the number of pods per plants depicted that maximum number of pods per plant (2002) was observed in T₉ (15 × 30 cm) which was statistically at par with T₆ (10 × 30 cm), T₇ (15 × 10 cm) and T₈ (15 × 20 cm). The minimum number of pods per plant (1014) was recorded from T₂ (5 × 20 cm) which was statistically at par with T₁ (5 × 10 cm) and T₃ (5 × 30 cm) (Table 2). Number of pods per plant depends upon the number of primary and secondary branches as more were observed in wider spacing which ultimately gives higher number of pods. The results are in line with the observations of Momoh and Zhou (2001) who stated that the number of effective branches and pods per branch decreased with increasing plant density. Higher branching observed in wide row spacing was a major cause of the increased number of pods per plant.

Table 1. Meteorological data during crop growth period

Month	Rainfall (mm)	Mean Min. Temp. (°C)	Mean Max. Temp. (°C)	Mean Temp. (°C)
October	23.0	16.3	30.8	23.5
November	1.0	8.8	26.5	17.6
December	57.0	6.8	21.0	13.9
January	68.0	6.0	18.6	12.3
February	34.0	7.6	20.4	14.0
March	28.0	11.8	26.2	19.0
April	72.5	12.3	31.3	21.8
Mean	40.5	9.9	24.9	17.5

Table 2. White mustard plant characters under inter and intra row spacing

Treatments	Plant height (cm)	No. of pods / plant	No. of seeds / pod	1000 seed weight (g)	Seed yield (Kg ha ⁻¹)
T ₁ (5 × 10cm)	132.4 d	1063 d	4.16 bcd	4.74 abc	1766 bc
T ₂ (5 × 20cm)	135.0 d	1014 d	4.26 bc	4.88 ab	1902 ab
T ₃ (5 × 30cm)	136.8 cd	1213 cd	4.23 bc	4.93 ab	1982 a
T ₄ (10 × 10cm)	136.6 cd	1553 bc	3.83 d	4.69 bc	1812 bc
T ₅ (10 × 20cm)	148.9 a	1547 bc	3.93 cd	4.65 bc	1704 cd
T ₆ (10 × 30cm)	145.1 abc	1715 ab	4.03 bcd	4.93 ab	1595 d
T ₇ (15 × 10cm)	138.3 bcd	1718 ab	4.36 ab	4.49 c	2046 a
T ₈ (15 × 20cm)	140.0 bcd	1767 ab	4.33 ab	4.68 bc	1569 de
T ₉ (15 × 30cm)	146.4 ab	2002 a	4.67 a	5.02 a	1428 e
LSD (P=0.05)	8.49	421.0	0.37	0.31	153.2

Any two means in a column not sharing a letter differ significantly at P > 0.05

Number of seeds per pod: The number of seeds per pod contributes considerably towards the final seed yield. The number of seeds per pod differed significantly among different treatments (Table 2). Maximum number of seeds per pod (4.667) was observed in T₉ (15 × 30 cm) which was statistically at par with the T₇ (15 × 10 cm) and T₈ (15 × 20 cm) but differed from rest of the treatments, while minimum number of seeds per pod (3.83) was recorded in T₄ (10 × 10 cm). Overall, plant growth, development and final stature would influence total seed setting. These results are in line with those of Ozer (2003) who stated that with increase in row spacing resulted consistent increase in the number of seeds per pod in rapeseed. Similarly, Hasanuzzaman *et al.* (2008) stated that the number of seeds per pod significantly decreased with the increase of population density of (*Brassica campestris* L.).

1000-seed weight (g): The weight of the seed expresses the magnitude of seed development which is an important yield determinant and plays a decisive role in showing off the yield potential of a crop. Plant spacing had significant effect on thousand grain weight (Table 2). The maximum 1000-seed weight (5.02 g) was observed in T₉ (15 × 30 cm), whereas minimum (4.49 g) 1000-seed weight of *Brassica*

campestris was attained by T₇ (15 × 10 cm). These results are in line with those of Hasanuzzaman and Karim (2007) who reported that higher 1000-seed weight of (*Brassica campestris* L.) was attained with wider plant spacing.

Seed yield (Kg ha⁻¹): Final seed yield of a crop is the expression of combined effect of various yield components. Planting density, number of primary and secondary branches, number of pods per plant, number of seeds per pod and 1000-seed weight are all the factors that contributing towards the seed yield. Plant spacing had significant effect on seed yield (Table 2). The maximum seed yield (2046 kg ha⁻¹) was recorded from T₇ (15 × 10 cm) which was statistically similar with T₃ (5 × 30 cm) but differed significantly from other remaining treatments. Whereas, the minimum seed yield (1428 kg ha⁻¹) was exhibited by T₉ (15 × 30 cm). These results are in analogy with the results of Misra and Rana (1992) and Gawai *et al.* (1994) who concluded that seed yield of *Brassica campestris* decreased with increase in row spacing.

Oil contents (%): An oilseed crop rich in oil content of high quality is the ultimate goal of a grower. The data pertaining to seed oil contents in Table 3 revealed significant the differences among treatments. The T₉ (15 × 30 cm)

Table 3. White mustard fatty acid profile percentage under inter and intra row spacing

Treatments	Oil contents (%)	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Eicosenoic acid (%)	Erucic acid (%)
T ₁ (5 × 10cm)	28.65 f	2.51 f	0.63 f	21.47 g	8.94 a	8.22 f	8.09 e	43.19 e
T ₂ (5 × 20cm)	29.54 e	2.58 ef	0.69 ef	21.93 f	8.85 ab	8.36 e	8.26 de	43.77 d
T ₃ (5 × 30cm)	30.87 cd	2.74 d	0.77 cde	22.18 de	8.75 bcd	8.50 c	8.45 cd	44.03 cd
T ₄ (10 × 10cm)	29.08 ef	2.60 e	0.72 de	21.99 ef	8.82 bc	8.41 de	8.33 d	43.67 d
T ₅ (10 × 20cm)	30.60 d	2.80 cd	0.83 bc	22.26 bcd	8.69 de	8.48 cd	8.56 bc	44.25 c
T ₆ (10 × 30cm)	31.54 b	2.87 bc	0.89 b	22.43 bc	8.61 e	8.63 ab	8.73 ab	44.75 b
T ₇ (15 × 10cm)	31.37 bc	2.76 d	0.79 cd	22.24 cd	8.74 cd	8.52 c	8.46 cd	44.19 c
T ₈ (15 × 20cm)	31.85 ab	2.89 ab	0.90 b	22.46 ab	8.59 e	8.62 b	8.77 ab	44.84 b
T ₉ (15 × 30cm)	32.21 a	2.96 a	0.98 a	22.66 a	8.37 f	8.71 a	8.92 a	45.76 a
LSD (P= 0.05)	0.58	0.07	0.07	0.21	0.11	0.07	0.22	0.39

Any two means in a column not sharing a letter differ significantly at P > 0.05

treatment accumulated the highest oil content (32.21%) which was statistically at par with T₈ (15 × 20 cm) but differed significantly from other treatments, whereas lowest oil content (28.65 %) were observed in T₁ (5 × 10 cm) which was statistically at par with T₄ (10 × 10 cm). The increase in oil content may be due to the effect of temperature during the physiological maturity stage. These results are in line with those of Sher *et al.* (2001) who promised that the oil contents increased with increasing planting density.

Palmitic acid (%): Significant differences among different treatments for Palmitic acid are presented in Table 3. The T₉ (15 × 30 cm) treatment accumulated the maximum (2.96%) palmitic acid which was statistically at par with T₈ (15 × 20 cm), but differed significantly from rest of the treatments whereas, minimum (2.510 %) palmitic acid was exhibited by T₁ (5 × 10 cm) which was statistically at par with T₂ (5 × 20 cm). Palmitic acid contents increased as the increase in plant to plant and row to row spacings. These results are in agreement with those of Cheema *et al.* (2001) who concluded that palmitic acid content increased significantly with increasing row spacing.

Stearic acid (%): Stearic acid is categorized as a saturated fatty acid and is an undesirable quality parameter. Differences among treatments for Stearic acid were found to be significant (Table 3). T₉ (15 × 30 cm) accumulated the highest stearic acid (0.98 %) differed significantly from other treatments. The lowest stearic acid (0.63 %) was observed in T₁ (5 × 10 cm) which was statistically at par with T₂ (5 × 20 cm). Our results are different from those of Gawai *et al.* (2001) who concluded that with the increase in row spacing significantly decreased stearic acid contents in *Brassica napus*.

Oleic acid (%): Results pertaining to oleic acid are presented in the Table 3 showed significant differences among different treatments. T₉ (15 × 30 cm) accumulated the maximum (22.66 %) oleic acid which was statistically at par with T₈ (15 × 20 cm) but differed significantly from remaining treatments. The minimum (21.47 %) oleic acid was exhibited by T₁ (5 × 10 cm). Higher oleic acid percentage might be due to higher temperature during the seed setting period. These results are in analogy with those of Cheema *et al.* (2001) who reported that the different row spacings affected significantly oleic acid contents.

Linoleic acid (%): Different treatments exhibited significant response for linoleic acid (Table 3). The T₁ (5 × 10 cm) accumulated the maximum linoleic acid (8.937 %) which was statistically at par with T₂ (5 × 10 cm) but differed significantly from rest of the treatments. The minimum linoleic acid (8.367 %) was observed in T₉ (15 × 30 cm). Low average temperature during seed development might have given higher linoleic acid in closer inter and intra row spacing plants. However, Cheema *et al.* (2001) reported that the linoleic acid contents increased with an increase in row spacing.

Linolenic acid (%): The results presented in the Table 3 revealed statistically significant differences among treatments for linolenic acid. The T₉ (15 × 30 cm) treatment accumulated the maximum (8.71%) linolenic acid which was statistically at par with T₆ (10 × 30 cm) but differed significantly from rest of the treatments. The minimum (8.22%) linolenic acid was exhibited by T₁ (5 × 10 cm). These differences may be attributed to the prevailing temperature at physiological maturity stage. A linolenic acid contents in *Brassica napus* L. increased with the increase in plant spacings (Malik *et al.*, 2004).

Eicosenoic acid (%): The results revealed that different inter and intra row spacings were exhibited statistically significant differences for eicosenoic acid (Table 3). T₉ (15 × 30 cm) accumulated the maximum eicosenoic acid (8.923 %) which was statistically at par with T₈ (15 × 20 cm) but differed significantly from rest of the treatments. The minimum eicosenoic acid (8.090 %) was observed in T₁ (5 × 10 cm). Eicosenoic acid contents of (*Brassica campestris* L.) increased gradually with the increase in plant to plant and row to row spacing in (Gawai *et al.*, 1994).

Erucic acid (%): The results presented in the Table 3 revealed the mean values of different treatments for erucic acid. It is evident that different treatments exhibited statistical significant differences for erucic acid. The T₉ (15 × 30 cm) accumulated the maximum (45.76 %) erucic acid while the minimum (43.19 %) erucic acid was recorded in T₁ (5 × 10 cm). Higher erucic acid percentage might be due to higher temperature during the seed setting period. Our findings are contrary to Cheema *et al.* (2001) who suggested that with the increase in row spacing markedly reduced the erucic acid contents.

CONCLUSIONS

This study suggests that *Sinapis alba* yield was significantly affected by row to row and plant to plant spacings and was higher at the narrow (15 × 10 cm) row and plant spacings compared to the wider (15 × 30 cm) spacing. Thus, it is concluded that *Sinapis alba* should be grown at 150 cm grids for higher yield output.

REFERENCES

- Abu-Darwish, M.S., A.H. Al-Fraihat, S.Y.A. Al-Dalain, F.U. Afifi and J.A. Al-Tabbal, 2011. Determination of essential oils and heavy metals accumulation in *Salvia officinalis* cultivated in three intra-row spacing in ash-shoubak, Jordan. Int. J. Agric. Biol. 13:981–985.
- Ahmad, M., A. Khaliq, R. Ahmad and A.M. Ranjha. 2010. Allometry and productivity of autumn planted maize hybrids under narrow row spacing. Int. J. Agric. Biol. 12:661–667.

- Beg, A., S.S. Pourdad and S. Alipour. 2007. Row and plant spacing effects on agronomic performance of sunflower in warm and semi cold areas of Iran. *Helia*. 30:99-104.
- Bodnaryk, R.P. and R.J. Lamb. 1991. Mechanisms of resistance to the flea beetle *Phyllotreta cruciferae* Goeze in mustard seedlings *Sinapis alba* L. *Can. J. Plant Sci.* 71:13-20.
- Cheema, M.A., M. Saleem and M.A. Malik. 2001. Effect of row spacing and nitrogen management of agronomic traits and oil quality of canola. *Pak. J. Agri. Sci.* 38:15-18.
- Duke, J.A. 1978. The quest for tolerant germplasm. p. 1-61. In: Crop tolerance to suboptimal land conditions. *Am. Soc. Agron. Special Symp.* 32, Madison, WI.
- Gawai, P.P., C.S. Chaudhari, N.G. Zade and S.Q. Darange. 1994. Response of mustard to nitrogen fertilization and spacing. *J. Plant Sci.* 4:6-44.
- Hasanuzzaman, M., M.F. Karim and M.J. Ullah. 2008. Growth dynamics of rapeseed (*Brassica campestris* L.) cv. SAU sarisha as influenced by irrigation levels and row spacings. *Aust. J. Bas. Appl. Sci.* 2:794-799.
- Hasanuzzaman, M. and M.F. Karim. 2007. Performance of Rapeseed (*Brassica campestris* L.) cv. SAU sarisha under different row spacings and irrigation levels. *Res. J. Agri. Bio. Sci.* 3:960-965.
- Leach, J.E., J.H. Stevenson, A.J. Rainbow and L.A. Mullen. 1999. Effects of high plant populations on the growth and yield of winter oilseed rape (*Brassica napus* L.). *J. Agric. Sci.* 132:173-180.
- Momoh, E.J.J. and W. Zhou. 2001. Growth and yield responses to plant density and stage of transplanting in winter oilseed Rape (*Brassica napus* L.). *J. Agron. Crop Sci.* 186:253-259.
- Malik, M.A., M.F. Saleem, A. Aziz and Jehanzeb. 2004. Agro-physiological response of Canola (*Brassica napus* L.) to different planting patterns and stand densities. *Pak. J. Life Soc. Sci.* 2:148-152.
- Ministry of Finance. 2011. Economic survey of Pakistan. p. 21. Finance and Economic Affairs Division, Ministry of Finance, Govt. of Pakistan, Islamabad, Pakistan.
- Misra, B.K. and N.S. Rana. 1992. Response of yellow sarsoon to row spacing and nitrogen fertilization under late sown condition. *Ind. J. Agron.* 37:847-848.
- Norsworthy, J.K. and R.S. Emerson, 2005. Effect of row spacing and soybean genotype on main stem and branch yield. *Agron. J.* 97:919-923.
- Oad, F.C., B.K. Solangi, M.A. Samo, A.A. Lakho, Z.U. Hassan and N.L. Oad. 2001. Growth, yield and relationship of Rapeseed (*Brassica napus* L.) under different row spacing. *Int. J. Agric. Biol.* 3:475-476.
- Ozer, H. 2003. The effect of plant population densities on growth, yield and yield components of two spring rapeseed cultivars. *Plant Soil Environ.* 4:422-426.
- Sangoi, L. 2000. Understanding plant density effects on maize growth and development: an important issue to maximise grain yield. *Cienc. Rural* 31:159-168.
- Sher, R.U., M.A. Malik and A. Ali. 2001. Biological expression of Raya (*Brassica juncea* L.) grown under different planting patterns and inter plant spacing. *Int. J. Agric. Biol.* 3:214-216.
- Steel, R.G.D., J.H. Torrie and D.A. Dickny. 1997. Principle and procedures of statistics: A biometrical approach, 3rd ed. McGraw Hill Book Co., Inc., NY, U.S.A.