REVIEW OF LITERATURE

Growing of two or more crops simultaneously in the same field for higher yield and increased economic returns is important in the present context of agricultural scenario. The per capita availability of cultivable land has been shrinking due to increasing demographic pressure. Currently intercropping may be boon to produce higher yield per unit area, in turn generate more income under specific set of conditions particularly row ratio as replacement series in wheat and mustard. At present, row intercropping has been proved to produce higher yield advantage over mixed intercropping. Intercropping system offer increased cropping intensity as two or more crops occupy the land simultaneously. The available research information on wheat and mustard intercropping has been reviewed and presented in this chapter.

2.1 Intercropping systems and their importance

Singh and Katyal (1966) reported that the intercropping is mainly practiced to cover the risk of total failure of any one of the component crops due to vagaries of weather, pest or disease incidence. Yield advantages in intercropping systems are mainly due to differential use of growth resources by the component crop.

Willey (1979) observed that mechanism for complementarily is to occur when the growth patterns of component crops differ in time. The yield advantages in intercropping systems are associated with full use of environmental resources over time.

Sarkar and Shit (1990) reported that intercropping not only stabilizes crop production by reducing the impact of weather vagaries insect-pest and weed infestation.

2.2 Wheat based intercropping

Raj Vir Singh (2003) observed that the nitrogen uptake in grain and straw of wheat was found to be significantly higher in 10:2 rows ratio of wheat and mustard which was at par with 6:2 row ratios as compared to remaining row ratios.

Ghosh (2004) observed that the Fertilizers of NPK applied to both crops in the system significantly increased the dry matter, grain yield of wheat in all the nutrient levels.

Srivastava et al. (2007) observed that wheat produced significantly lower grain yield in
intercropping system than its sole stand. Besides lower plant population, the more competitive and aggressive intercrop contributed in lowering the wheat grain yield in intercropping.

Chengci Chen et al. (2008) observed that the yield increase at narrow row spacing could not be achieved by increasing seeding rate at wide row spacing in wheat crops.

Manjit et al. (2009) observed that wheat as sole crop recorded significantly higher grain yield (1185 kg ha⁻¹), straw yield (2172 kg ha⁻¹), 1000 grain weight (39.68 g), total dry matter production (7.18, 43.55 and 57.71 g 0.5 m⁻¹ row length) at different stages of crop growth than intercropped wheat.

Dahmardeh et al. (2010) observed that resources such as water, light and nutrients can be utilized more effectively in intercropping than in the respective sole cropping system.

Singh, A.K. and Bohra, J.S. (2012) reported that in wheat + mustard intercropping system, application of increasing fertilizer doses from 100% to 140% RFD to wheat accompanied with 100% RFD to mustard exhibited significant increase in spikes/m, average spike length, and grains/spike. This could be attributed to greater absorption of nitrogen, phosphorus and potassium at higher fertility levels, which led to increased photosynthesis production and accumulation.

2.3 Effect of fertilizer on mustard

Ghosh et al. (1995) reported that fertilizer has the pivotal role in increasing crop production. Besides N and P, the use of K has been reported to influence productivity of seed yield and seed oil contents in mustard.

Patil et al. (2004) conducted a field experiment on Indian mustard to investigate effect of N fertilizer at 75, 100 and 150 kg per ha. The combination of irrigation + 100 kg N per ha + 45 cm spacing resulted in a significant increase in seed yield and other yield attributes.

Sinsinwar et al. (2004) applied the N fertilizer at rates of 0, 30, 60 and 90 kg per ha. Significant increase in mustard seed yield was noticed with each increment of N fertilizer up to 60 kg per ha. On average, the increase in seed yield was about 33.3 and
83.8 per cent with 30 and 60 kg N per ha, respectively as compared to the control.

**Shah et al. (2004)** investigated that effect of N and P combination (50:15, 75:30, 100:45, 125:60 and 150:75 kg/ha) on oil content of Indian mustard. Oil content percentage was highly influenced by cultivars, NP levels and their interaction. Seed oil content increased with increasing NP levels and it was maximum with highest NP combination of 150:75 kg per ha.

**Sah et al. (2006)** reported that increasing the nitrogen level up to 90 kg/ha increased the number of secondary branches per plant, number of siliqua per plant, seed and straw yield with maximum cost benefit ratio of 3.03.

**Ravi et al. (2006)** reported that yield attributes of Indian mustard viz., siliqua plant$^{-1}$, grains per siliqua and 100 seed weight were significantly higher in BG 1003 + Varuna, mustard + chickpea intercropping system than the other intercropping systems.

**Sharma et al. (2007)** observed that increasing of nitrogen level up to 90 kg/ha increased the number of secondary branches per plant, number of siliqua per plant, seed and straw yield with maximum cost benefit ratio of 3.03.

**Mir et al. (2010)** reported that the optimum effect of the application of 60 kg P$_2$O$_5$ ha$^{-1}$ on seed yield was presumably due to maximum pods/plant, seed/pod and seed weight, as these parameters were found to be positively correlated with yield of the crop. The seed yield and oil yield increased by application of fertilizers 60 kg P$_2$O$_5$ ha$^{-1}$.

**Shekhawat et al. (2012)** observed that combined application of 10 t FYM + 90:45:45 NPK kg/ha with *Azotobacter* inoculation in mustard gave the highest B:C ratio of 1.51 than other lower.

**2.4 Effect on wheat and mustard intercropping system with row ratio**

**Mandal et al. (1985)** suggested that wheat, mustard and chickpea grown alone, or wheat in combination with mustard and chickpea affected branching and plant height in mustard and chickpea. However, wheat + mustard intercropping in 4:2 and 10:2 row ratio though remained comparable but produced significantly higher mustard branches plant$^{-1}$ than 1:1 row ratio.
Sharma *et al.* (1986) reported that row ratios of 2:1, 5:1 and 8:1, respectively causing reduction in wheat yield of 48.7, 24.8 and 13.1%. The highest LER (1.25) was recorded in 3:1 row ratio of wheat + mustard as compared to sole and other treatments and next best LER was 1.24 in 5:1 row proportion of wheat + mustard intercropping system.

Mandal *et al.* (1991a) reported that wheat + chickpea intercrop produced higher LAI at 60 and 75 DAS followed by wheat + mustard. The LAI of sole wheat was significantly higher than the combined LAI of wheat + mustard at 90 DAS further sole crop of wheat significantly produced maximum dry matter, followed by wheat + chickpea and wheat + mustard at 60 and 75 DAS. In all cases accumulation of dry matter declined after 90 DAS except chickpea in which it continued to increase till 105 DAS.

Dutta *et al.* (1994) observed that the highest grain yield was recorded under sole wheat. Among intercropping systems, wheat + linseed 4:1 row proportion recorded the highest grain yield as compared to other intercropping systems.

Dutta *et al.* (1994) observed that, the highest LER was recorded with wheat + rapeseed 2:1 row proportion (1.19) as compared to other intercropping systems and next followed was wheat + rape seed (4:1) row ratio (1.11).

Singh *et al.* (1995) showed that effective tillers m\(^{-1}\) row length (74.3) and grain yield of wheat (31.4 q ha\(^{-1}\)) recorded significantly higher in sole crop of wheat as compared to intercropping systems. Among intercrops the 9:1 row ratio of wheat + mustard recorded higher effective tillers m\(^{-1}\) row length (69.3) and grain yield of wheat (27.4 q ha\(^{-1}\)) over other row proportions.

Arunachalam *et al.* (1995) observed that the highest LER in bengalgram + sesame 4:2 row ratio (1.56) followed by (1.49) as compared to pure crop and other intercropping treatments. The highest LER recorded in 9:1 and 6:2 row ratio of wheat + Indian mustard (1.14) intercropping system which was significantly higher over pure crop and other row ratios.

Singh *et al.* (1995) observed that highest LER recorded in 9:1 and 6:2 row ratio of wheat + Indian mustard (1.14) intercropping system which was significantly higher over pure crop and other row ratios.
Singh et al. (1995) reported that wheat + mustard intercropping with various row ratios viz., 3:1, 6:1, 9:1, 3:2, 6:2 and 9:2 recorded minimum number of branch plant$^{-1}$ of mustard at 3:1 row ratio and the maximum at 9:2 row combinations. However, the difference among various row ratios did not prove significant.

Manjit et al. (1995) reported that sole wheat recorded significantly higher grain yield (1185 kg ha$^{-1}$), straw yield (2172 kg ha$^{-1}$), 1000 grain weight (39.68 g), total dry matter production (7.18, 43.55 and 57.71 g 0.5 m$^{-1}$ row length) at different stages of crop growth than intercropped wheat. Among intercropping system, 5:1 row ratio of wheat + mustard recorded significantly higher wheat grain yield (1001 kg ha$^{-1}$), straw yield (1880 kg ha$^{-1}$), 1000-grain weight (39.55 g) and total dry matter production (6.85, 39.62 and 51.68 g 0.5 m$^{-1}$ row length) at different stages of crop growth than rest of the row proportions.

Kulmi and Chundawat (1997) reported that wheat + sunflower with 4:1 row ratio recorded highest land equivalent ratio (1.15) as compared to pure stand and other treatments. The chickpea + wheat 6:2 row ratio recorded highest LER (1.65) followed by chickpea + wheat (8:2) and chickpea + wheat (4:2) row ratio of about 1.58 and 1.55 as compared to sole and other intercropping systems.

Verma et al. (1997) reported that the grain yield of wheat remained unaffected when grown in association with Indian mustard (8:1) row ratio with bonus yield of mustard (0.36 to 2.79 q ha$^{-1}$) under 100% recommended fertilizer as compared to sole and other intercropping systems.

Punia et al. (1999) observed that the highest seed yield of mustard equivalent (1878 kg ha$^{-1}$) and net return (Rs 16657 ha$^{-1}$) were recorded under sole mustard followed by its intercropping with chickpea (1:5) row ratio. The highest LER was recorded in intercropping of mustard with chickpea as compared to sole and other intercropping systems.

Sunita Kujur et al. (2005) reported that wheat + mustard 5:5 row ratio recorded higher land equivalent ratio (1.15) as compared to sole and other row treatments. Wheat with Indian mustard under 5:1 row ratio was found to be more sustainable in turns of LER (1.08). The wheat + Indian mustard intercropped in 8:1 row combination under both
row spacing and mixed cropping of wheat and Indian mustard. The broad cast sowing system did not show significant difference in wheat as compared to yield of respective sole crop of wheat. The sole wheat recorded highest grain yield of 21.31 q ha\(^{-1}\) and it was significantly superior over to all the row combinations except 9:1 row ratio of wheat and mustard (20.0 q ha\(^{-1}\)).

Srivastava et al. (2007) observed that increasing proportion of Indian mustard from 2:1 to 8:1 row ratio of wheat + Indian mustard intercropping markedly reduced grains spike\(^{-1}\), effective tillers m\(^{-1}\) and 1000 grain weight of wheat. The lowest wheat yield was recorded with the highest mustard proportion when one row of Indian mustard was sown after every two rows of wheat. The area under wheat was reduced by 33.3, 16.7 and 11.1%.

Srivastava and Bohra (2006) observed that in wheat + Indian mustard intercropping system increasing the proportion of Indian mustard in the intercropping system markedly reduced the number of grains, weight of grain /spike, number of effective tillers/meter, 1000 grain weight and grain yield of wheat .The greatest nutrient uptake was obtained with a row ratio of 8:1 compared to 5:1 and 2:1.In Indian mustard the number of siliqua/plant decreased with the increase in the density of plants.

Satish kumar and rakesh kumar (2006) studies effect of growth, yield and nutrient uptake of finger millet as influenced by different cropping systems and fertility levels. The results revealed that intercropping finger millet grown with red gram (8:2) row ratio recorded significantly higher growth and yield parameters.

Srivastava et al. (2007) reported that wheat with mustard under 8:1 row ratio recorded the maximum values of Leaf Area Index (LAI) and DM accumulation of both the crops but the magnitudes of these parameters decreased markedly in 5:1 and the minimum was with 2:1 row ratio, whereas Harvest Index of wheat decreased significantly from 8:1 to 2:1 row ratio. However, the difference among treatments in respect to LAI and DM in both the component crops was highly pronounced at 60 days after sowing and onwards. On same pattern, growth attributes of both crops in various treatments was manifested in yield attributes and eventually reflected in biological and grain yields.

Rajeeve et al. (2008) observed that the yield obtained from pure stand of wheat was
significantly higher over mixed stand of wheat and mustard in 8:2 row ratios.

**Masoume et al. (2011)** reported that planting date and row spacing had significant influence on radiation distribution in plant population as well as photosynthesis. In this experiment, suitable planting date and narrow row spacing resulted in better distribution of radiant energy.

**Shekhawat et al. (2012)** reported that nitrogen use efficiency was greatly influenced by the rate, source, and method of fertilizer application. The rate of nitrogen depends upon the initial soil status, climate, topography, cropping system in practice and crop. Crop under zero tillage is also more productive (695 kg/ha) with 80 kg N/ha.

**2.5 Effect on intercropping of fertility levels**

**Thakuria and Gogoi (1996)** reported that three Indian mustard (TM2, TM4 and Varuna) and 4 levels of N (0, 40, 80 and 120 kg/ha), application of nitrogen significantly increased the seed yield and yield attributes up to 80 kg N per ha in all the three mustard varieties.

**Verma et al. (1997)** reported that the grain yield of wheat remained unaffected when grown in association with Indian mustard (8:1) row ratio with bonus yield of mustard (0.36 to 2.79 q ha\(^{-1}\)) under 100% recommended fertilizer as compared to sole and other intercropping systems.

**Chaniyara et al. (2002)** reported that optimums inter and intra row spacing is necessary for interception of sunlight to each strata of leaves. This will enhance the rate of photosynthesis and consequently the dry matter production which can ultimately increase the crop yield. Interaction effect between inter and intra row spacing was found significant.

**Bohra J.S and Srivastava R.K. (2002)** study the response of varying fertility levels (25, 50, 75 and 100% RDF). Significant improvement in yield and yield attributes (siliqua plant\(^{-1}\), test weight, siliqua length and seed yield plant\(^{-1}\)) were observed with increasing NPK levels from 25 to 100% of recommended dose.

**Raj Vir Singh (2003)** reported that nitrogen uptake in grain and straw of wheat was found to be significantly higher in 10:2 rows ratio of wheat and mustard was at par with
6:2 rows ratio as compared to remaining row ratios.

**Shah et al. (2004)** investigated that effect of N and P combination (50:15, 75:30, 100:45, 125:60 and 150:75 kg/ha) on oil content of Indian mustard cultivars. Oil content percentage was highly influenced by cultivars, NP levels and their interaction. Seed oil content increased with increasing NP levels and it was maximum with highest NP combination of 150:75 kg per ha.

**Ghosh et al. (2004)** suggested that application of 75% NPK in combination with poultry manure (PM) or Farm yard manure (FYM) or phosphorus compost (PC) in soybean and sorghum crops and 75% NPK in wheat produced significantly higher grain yield than those an inorganic fertilizer and saved 25% NPK fertilizer due to additional production of following wheat crop. Among the cropping systems, soybean as preceding crop recorded the highest seed yield of wheat and was on at par with that of soybean/sorghum intercropping system.

**Thakur (2005)** reported that seed yield also increased with increasing nitrogen levels being significantly highest with the application of 120 kg N/ha.

**Meenakshi Gupta et al. (2007)** reported that increasing fertility level from 75-125% of recommended dose decreased energy use efficiency productivity significantly application of nitrogen in three splits recorded higher energy use efficiency and energy productivity than treatments receiving nitrogen in two splits.

**Khatun et al. (2012)** observed that grain yield of wheat was significantly influenced by intercropping because higher competition for light, nutrient, water, and other growth component the significantly highest grain yield (2.011 t ha⁻¹) was obtained from wheat sole crop.