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Performance of Mustard as Intercrop in *Eucalyptus tereticornis* based Cropping System in Semi-Arid Ecosystem of India

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ABSTRACT: To evaluate the effect of eucalypts plantation (2.8 years old) on growth, yield attributes and yields of mustard the present investigation was carried out. The plant height of mustard was significantly lesser under eucalypts plantation as compared to sole cropping. Days to 50% flowering (63.1) and maturity (146.2) were higher in mustard intercropped with eucalypts than sole mustard. Plants per meter row length, number of siliqua/plant, seeds per siliqua and test weight were recorded higher under sole mustard than eucalypts based agroforestry system. Grain and stover yield significantly declined under eucalypts over control (sole mustard). Per cent decrease in grain yield of mustard under eucalypts over control was 17.65. The net return from eucalypts based cropping system were Rs. 92037/ha while extremely low net returns (Rs. 11324/ ha) was obtained from sole mustard cropping system.

Keywords: Eucalypts, mustard, agroforestry, siliqua, yield.

INTRODUCTION

The 'red gum,' *Eucalyptus terreticornis*, native to Australia and Papua, New Guinea, is one of the fast growing tree species that has spread throughout the world. Due to its rapid growth rate, adaptability to a wide range of climatic and edaphic conditions and diverse uses, it has been encouraged in many tropical countries (Zobel *et al.*, 1987; Evans, 1992; Kumar *et al.*, 2013). It is the most preferred tree for planting around the boundaries, or bunds of agricultural fields. Eucalypts is resistant to salinity and has great potential in reclaiming wastelands and even act as a bio-drainage plant. Presently, a eucalypts plantation is in 95 nations with a total plantation area of more than 22.57 million hectares (Zhang and Wang 2021). Owing to its assured marketing and profitable returns, eucalypts is the most preferred species for agroforestry plantations in India (Prasad *et al.*, 2010; Dhillon *et al.*, 2018). It is also one of the most effective ways to increase tree cover in the forest. In present scenario, agroforestry is the only way to address the agricultural and ecological issues *i.e.* soil degradation, large-scale deforestation, increasing human and animal population pressure and a shrinking land-to-man ratio. Trees primarily alter radiations, carbon dioxide concentration, relative humidity, soil environment and wind speed (Dhillon *et al.*, 2016; Ahlawat *et al.*, 2019). Mustard is a major oilseed crop in the Cruciferae family, ranking second only to peanuts in terms of importance among oilseed crops. In India, the total cultivated area and production of rapeseed mustard is 6.78 mha and 9.12 million tones, respectively with average yield is 1345 kg/ha. (Anonymous, 2021). Kidanu *et al.* (2005) found that the significant reduction in grain yield of mustard in the first 12 m from the tree line of eucalypts boundary plantation and the reduction in grain yield was 20 to 51% over control (sole crop). Therefore, present investigation was designed to assess the growth, yield attributes and yield of mustard and economic returns under eucalypts-mustard based cropping system.

MATERIALS AND METHODS

The experiment was carried out in the research field of Forestry department, CCS Haryana Agricultural University, Hisar, India situated at 29^{o} 09′N latitude and 75^{o} 43′E longitude at an elevation of 215.2 m above mean sea level. The climate is subtropical-monsoonal with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with mean maximum temperature ranging from 40 to 45^{o}C (May and June) whereas; lowest temperature may reaches as low as 0°C (December and January). The mean monthly values of weather parameters *viz*., temperature, relative humidity, evaporation and rainfall were recorded during the period of experimentation (Fig. 1).

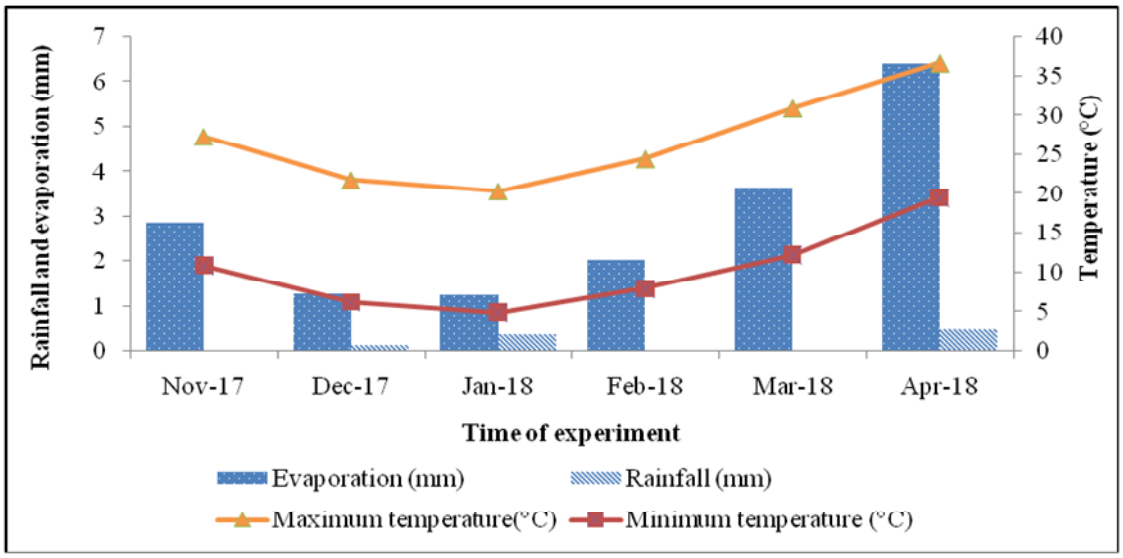

Fig. 1. Meteorological data of research site during experimentation.

Mustard was sown in *Eucalyptus terreticornis* (7×3 m) as well as sole crop (devoid of tree) during the first fortnight of October 2017-18 with row to row distance of 30 cm and seed rate of 3 kg ha^{-1}. As per the package and practice of the university, recommended doses of fertilizer (59.28 kg N, 19.76 kg P_2O_5 and 25 kg ha^{-1} zinc sulphate) were applied. The half amount of N and whole amount of P and zinc sulphate was applied at the time of sowing. The remaining dose of N through urea was top dressed at1st irrigation. Five plants selected randomly from each plot were tagged for recording plant height at 30, 60, 90, 120 DAS and at harvest.The fresh and dry matter accumulation was recorded in gram (g) using quadrant of 1m^2 from each plot in four replications by first taking the fresh weight (green weight of root, stem and leaves). After air drying, the plants were dried in the oven at 72^{0}C till the constant weight achieved. The numbers of plants were counted at 20 days after sowing (DAS) in each plot in a running meter row length at four places. The number of days taken to 50 % flowering, duration of maturity, number of siliqua/plant, siliqua length, number of seeds/siliqua were recorded under eucalypts as well as from sole crop. From the representative sample of each plot, 1000 seeds were counted and weighted to record the test weight of seeds in grams. Crop was harvested at physiological maturity. After sun drying, crop was threshed and the seed and stover yield from each plot were weighed. Bundles of each plot were then weighed (kg) before threshing to record the biological yield and converted to t ha^{-1}. The harvest index for each plot was calculated as under:

Harvest Index (%) = [Seed yield/Biological yield] × 100

The B:C ratio of both systems (eucalypts-mustard and sole mustard) was also calculated.

RESULTS AND DISCUSSION

Number of plants per meter row length: The number of plants per meter row length in mustard at 20 days after sowing (Table 1) showed significant variation between eucalypts based cropping system and control. The numbers of plants per meter row length were significantly higher (7.5) in control (devoid of tree) than under eucalypts plantation (5.4). The reduction in numbers of plants per meter row length at 20 DAS in mustard was 28.0 per cent under eucalypts plantation over control. The reduction in number of plants in mustard under eucalypts plantation may be due to availability of low light intensity. Availability of low solar radiation hinders the germination of crop which ultimately affects the plant population under eucalypts plantation (Kumar *et al.*, 2013).

Table 1: Number of plants per meter row length in mustard at 20 DAS under eucalypts plantation and control (sole mustard).

Treatment	Plants/mrl
Eucalypts + mustard	5.4
Control (Sole mustard)	7.5
t-value	4.74*

*Significant at 5 per cent level of probability

Plant height (cm) at different time intervals: The effect of eucalypts plantation under study on plant height of mustard at various growth stages is represented in Fig. 2. The results showed that plant height increased with successive stages of crop growth, however, maximum rate of increase in height was recorded between 30 and 60 DAS in eucalypts based cropping system as well as control. The results clearly indicate that mustard showed significantly lesser plant height under eucalypts plantation in comparison to control (without tree) from 30 DAS up to harvesting. The maximum plant height (181.2 cm) was found at harvest which was statistically at par with 120 DAS (179.3 cm) under control (sole mustard). While the maximum reduction in plant height was recorded 31.16,

11.60, 15.67, 13.44 and 13.02 % at 30, 60, 90,120 DAS and at harvest, respectively under eucalypts based cropping system over control. Kumar and Nandal (2004) estimated the performance of mustard under *Eucalyptus teriticornis* and reported that mustard grown as inter crop in the interspaces of eucalypts showed reduced plant height as compared to control.

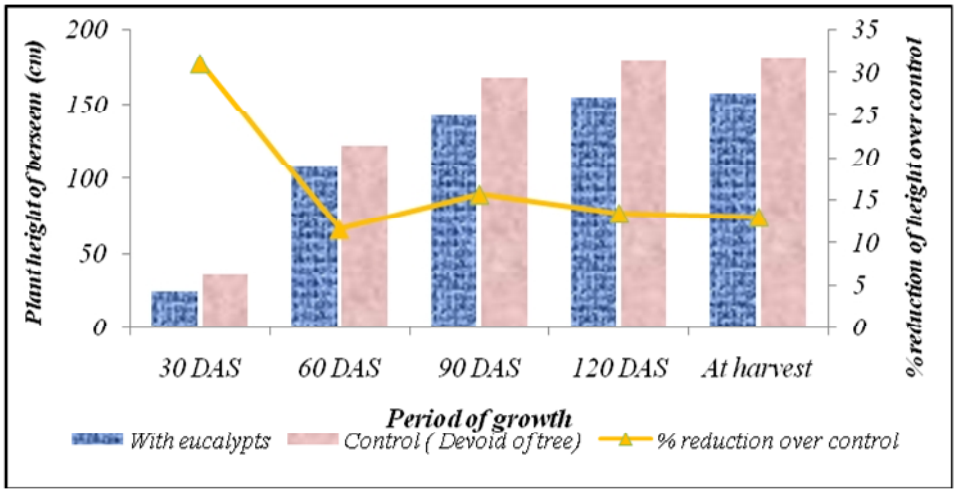

Fig. 2. Mustard plant height (cm) at 30 days interval under eucalypts plantation and in control (devoid of tree).

Fresh and dry matter accumulation (g m^{-2}) at different time intervals of growth: The fresh and dry matter accumulation of mustard (Fig. 3) was affected significantly in eucalypts plantation than control (without tree). Fresh and dry matter accumulation increased substantially with the increase in mustard. However, maximum increase in fresh and dry matter accumulation was observed between 30 to 60 DAS of crop stage. Thereafter, it increased but at slow rate. Mustard intercropped with eucalypts accumulated lower fresh and dry matter at various stages of growth however; it attained maximum dry matter under control (sole mustard). Mustard grown in interspaces of eucalypts showed a maximum reduction in fresh and dry weight 8.09, 15.66, 13.02, 20. 72, 14.37% and 6.67, 12.94, 11.57, 19.35 and 12.22% at 30, 60, 90, 120 DAS and at harvest, respectively over control (devoid of tree). The lesser biomass accumulation in mustard under eucalypts based cropping system may be due to the accessibility of lesser solar radiation and higher competition between tree and crop for moisture and nutrients than in control (devoid of tree). In addition allelopathic effect of eucalypts is also responsible to reduce biomass accumulation in mustard (Deswal and Nandal, 2008; Prasad *et al.*, 2011).

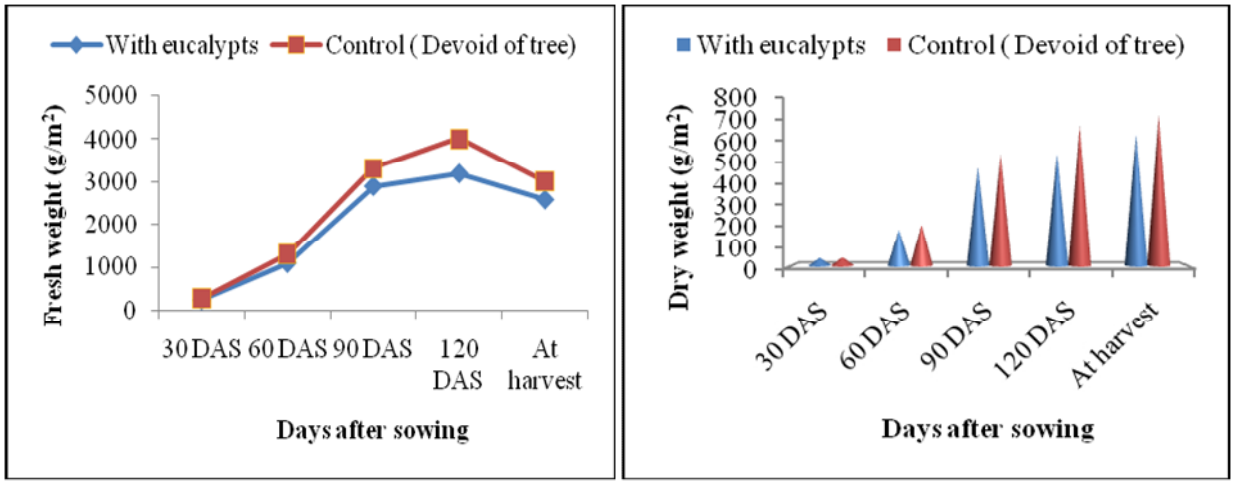

Fig. 3. Fresh and dry matter accumulation (g m^{-2}) at 30 days interval and at harvest in mustard under eucalypts plantation and control (sole mustard).

Phenological characters: The data evidenced on phonological development (days to 50% flowering and days to maturity) in mustard under varying cropping system (eucalypts based agroforestry system and control) are presented in Table-3. Eucalypts based cropping system had significant effect on the number of

days taken to 50% flowering and days to maturity in mustard. Mustard sown under eucalypts based agroforestry system took higher number days to 50% flowering (63.1) and maturity (146.2) ascompared to control (57.8 and 135.7), respectively. In eucalypts based cropping system, maturity of mustard was delayed by about 10 days over control (sole crop). The maximum number of days taken for spike emergence (50%) and maturity of mustard under eucalypts plantation were relatively more due to deprived photosynthetic ability of crop (Dhillon *et al.,* 2016).

Table 3: Phenology of mustard under eucalypts plantation and control (sole mustard).

Treatments	Number of days taken	
	Flowering (50%)	Maturity
Eucalypts + mustard	63.1	146.2
Control (Sole mustard)	57.8	135.7
t-value	5.52*	5.25*

*Significant at 5 per cent level of probability

Siliqua length (cm), number of siliqua/ plant, number of seed/ siliqua and test weight (g): The results in Table 4 showed that the maximum siliqua length (6.2 cm) of mustard was observed in control (sole crop) as compared to eucalypts based cropping system. Eucalypts plantation under study exhibited 11.29 per cent reduction in siliqua length of mustard over control. The number of siliqua/plant in mustard also exhibited similar trend as that of siliqua length under eucalypts as well as control. The results showed that the number of siliqua/plant under varying cropping system differed significantly (eucalypts based agroforestry system and control). Significantly higher numbers of siliqua/plant (275.3) were observed in control. Per cent reduction in number of siliqua/plant was 30.84 under eucalypts plantation over control (sole mustard). The number of seeds/siliqua differed significantly under both cropping system (eucalypts based agroforestry system as well as control). The results showed that mustard grown in interspaces of eucalypts plantation exhibited minimum number of seeds/siliqua (10.2) than control (16.3). Per cent reduction in number of seeds/siliqua was 37.42 in eucalypts over control. In control, mustard exhibited significantly higher test weight (5.6 g) than under eucalypts. The percent reduction in test weight of mustard was 19.64 under eucalypts based cropping system over control (devoid of tree). Kumar *et al.* (2013) reported that number of siliqua/plant in mustard were significantly higher when intercropped with eucalypts based agroforestry system. They found that the number of siliqua per plant was 371 in sole cropping and 84.2 were found under eucalypts based agroforestry system. Similar findings were also reported by Pervin *et al.* (2015) who reported the decrease in number of siliqua per plant in mustard near the tree line of *Albizia lebbeck* and it increased with the increasing distance from tree line. The results of present investigation are also in line with the studies of Shah (2013) in which the lesser number of siliqua in mustard near the tree line of eucalypts and *Xylia dolabriformis*. The reduction in number of siliqua per plant under eucalypts plantation may be ascribed to more competition for light, moisture and nutrients (Prasad *et al.,* 2011). In control, mustard exhibited significantly higher test weight (5.6 g) than under eucalypts. The reduction in test weight of mustard was 19.64 per cent under eucalypts based cropping system over control. The reduction in seed test weight of mustard was in association with *Xylia* and Lohakt tree species also been earlier reported (Farhana *et al.,*2013; Kundu *et al*., 2014).

Table 4: Yield attributes of mustard under eucalypts plantation and control (sole mustard).

Treatment	Siliqua Length (cm)	Number of siliqua/plant	Numberof seeds per siliqua	Testweight (1000 grain wt)(g)
Eucalypts + mustard	5.5	190.4	10.2	4.5
Control (Sole mustard)	6.2	275.3	16.3	5.6
t-value	4.12*	9.27*	12.74*	13.08*

*Significant at 5 per cent level of probability

Grain yield (t/ha), Straw yield (t/ha), Biological yield (t/ha) and Harvest index (%): The grain yield of mustard was observed maximum (1.7 t/ha) in control (sole mustard) than under eucalypts based cropping system (Table-5). The per cent decrease in grain yield of mustard under eucalypts plantation over control was 17.65. The straw yield of mustard was also affected under eucalypts and maximum straw yield (2.6 t/ha) was observed in control than under eucalypts based cropping system and the per cent reduction in straw yield of mustard was 15.38 under eucalypts over control. However, the rate of decrease in straw yield was comparatively lower than grain yield of mustard under eucalypts plantation. The biological yield of

mustard under eucalypts based cropping system reduced up to 16.28% over control. The results showed that sole mustard (control) exhibited maximum harvest index (39.5%) than under eucalypts plantation. The per cent reduction in harvest index of mustard under eucalypts based agroforestry system was 1.77 over control. The lesser accessibility of solar radiation, soil moisture and nutrients may be responsible for reduction in yield of mustard under eucalypts plantation (Shah, 2013).

Table 5: Yield of mustard under eucalypts plantation and control (sole mustard).

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Eucalypts + mustard	1.4	2.2	3.6	38.8
Control (Sole mustard)	1.7	2.6	4.3	39.5
t-value	4.00*	1.80	5.56*	0.18

*Significant at 5 per cent level of probability

Economic analysis of the eucalypts based agroforestry system: The total cost of cultivation (Rs. ha^{-1}) was found higher (Table-6) in mustard under eucalypts based system, i.e., eucalypts + mustard (Rs. 132390.7) as compared to sole mustard (Rs. 52213.9). The gross return was found higher in eucalypts based agroforestry systems (Rs. 224428.5), while the lower gross return was obtained with the sole cropping of mustard (Rs. 63538.2). The maximum net return (Rs. 92037.8) was observed with eucalypts + mustard cropping system. The higher B:C ratio (1.69) was obtained in eucalypts + mustard system over control (1.21). The present study clearly shows that the gross return and net return were found more in eucalypts + mustard based cropping system than sole traditional cropping of mustard. Banerjee and Dhara (2011) reported higher net return under agroforestry system as compared to sole cropping. Also, Kaushik *et al.* (2017); Dhillon *et al*. (2018) revealed higher gross return under tree based cropping system over sole crops. The loss in crop yield under trees can be compensated by the income returns from the tree component at the end of the rotation (Satyawali *et al*, 2018).

Table 6: Economics of eucalypts based agroforestry system (eucalypts + mustard) and control (sole mustard).

Particulars	Agroforestry (eucalypts + mustard)	Sole crop (mustard)
Cost of cultivation (Rs./ha)	132390.7	52213.9
Gross return (Rs./ha)	224428.5	63538.2
Net return (Rs./ha)	92037.8	11324.3
Cost/benefit ratio	1.69	1.21

CONCLUSION

In this study, growth, biomass accumulation, yield attributes, grain, straw and biological yield of mustard were observed to decline under eucalypts based cropping system as compared to sole mustard. However, the overall findings of the present study elucidates that tree based cropping system (agroforestry) is more profitable as the tree component sale at the harvesting age not only compensate the yield reduction of agricultural crops but also adds a huge amount of net returns as compared to sole cropping (devoid of tree). Therefore, agroforestry system not only mitigate the climate change through carbon sequestration, improves soil health but also bestow extra income to the farmers/stakeholders.

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Conflict of Interest. None.

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