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Weed management in sugarcane-canola intercropping systems in northern India

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ABSTRACT

Intercropping has the potential to increase total system productivity, monetary returns, and resource utilization in long duration crops such as sugarcane. The suitability of canola (oilseed rape & Indian mustard) for intercropping in autumn planted sugarcane and the efficacy of herbicides for weed control in these intercropping systems was investigated over two years. Three cropping systems (sole sugarcane, sugarcane–oilseed rape and sugarcane-Indian mustard) and six weed control treatments were investigated. Sugarcane–oilseed rape and sugarcane-Indian mustard intercropping systems produced cane yield (73.6–88.6 t ha^{-1}) similar to sole sugarcane (78.4–85.3 t ha^{-1}). When grown as intercrops with sugarcane, oilseed rape produced seed yield of 1.47–1.59 t ha^{-1} while Indian mustard produced 2.51–2.95 t ha^{-1}. Sugarcane–oilseed rape and sugarcane-Indian mustard systems increased the net returns by 1.3 and 1.7-fold as compared to sole sugarcane (USD 1674 ha^{-1}). Indian mustard exhibited higher weed suppression than oilseed rape and sole sugarcane, which may be associated with greater production of secondary branches and planting arrangement of Indian mustard (2-rows) as compared to oilseed rape (1-row). Pre-emergence application of pendimethalin at 0.75 kg and alachlor at 1.875 kg ha^{-1} provided adequate control of weeds in these intercropping systems and increased the seed yield of oilseed rape and Indian mustard relative to the weedy check by an average of 41% and 15%, respectively. The use of these pre-emergence herbicides increased the net returns by USD 286–317 ha^{-1} as compared to the weedy check.

1. Introduction

Sugarcane was grown on 5.03 million hectares (M ha) in India in 2013–14, with cane production of 356 million tonnes (MT) and 28.0 MT of sugar (www.indiastat.com). Still India imported 0.07 MT of sugar to meet its domestic demand. In north Indian states of Punjab, Haryana and Uttar Pradesh, sugarcane is planted in three seasons i.e. autumn, spring or summer. Autumn-sown crops have been shown to produce 25–30% greater cane yields than spring sown crops and 40–50% higher yield than the summer sown crops (Rana et al., 2006). However, the autumn planted crop occupies the field for more than one year and the farmers have to forego one winter season crop. Sugarcane in India is planted in wide rows (90 cm inter-row space), but the growth of autumn sown crop slows down, during the winter months, soon after emergence. Usually this wide inter-row space is invaded by weeds. However, it is feasible to utilize the vacant inter-row space for growing short duration intercrops (4–5 months) during the early growth period of autumn sugarcane. The intercrops could compete with weeds and enhance total productivity and profitability of autumn sugarcane. However, selection of intercrops for this purpose needs to be done carefully to avoid the risk of excessive inter-specific competition with sugarcane.

Previous studies on intercropping in sugarcane have reported variable effects of intercrops on sugarcane yield. Shukla and Pandey (1999) in India and Ali et al. (2001) in Pakistan recorded no adverse effects of mustard and lentil intercropping on cane yield. Cadersa et al. (2001) from Mauritius reported similar cane yield from sole and potato intercropped sugarcane. Similarly, the intercropping of velvet bean (*Mucuna deeringiana*), sugar bean (*Phaseolus limensis*) and sweet potato (*Ipomoea batatas*) recorded no adverse effect on cane yield (Berry et al., 2009). In contrast, sugarcane intercropped with sunflower reduced cane yield than sole sugarcane (Afzal et al., 2003). Similarly, Munoz et al. (2001) in Cuba obtained lower yield of sugarcane intercropped with peanuts or maize fodder, however, the total system productivity and prof-

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itability from intercropping was greater than sole sugarcane. Weed competition can reduce sugarcane yield by 20–90% (McIntyre, 1991). Even though intercropping can provide some weed suppression, it may not be sufficient to avoid yield losses due to weeds. Hence, the acceptance of intercropping systems by local growers would need development of effective weed management tactics. In sole sugarcane, farmers control weeds with herbicides and tillage. However, herbicides commonly used for weed control in sole sugarcane cannot be used as such in an intercropping system because of toxicity to the intercrops, and inter-row tillage is also difficult because of intercrops present in the inter-row spaces. In sugarcane–wheat intercropping system, clodinafop-propargyl and fenoxaprop-p-ethyl were safe to wheat but toxic to sugarcane (Bhullar et al., 2008b). Atrazine (Patil et al., 1991), metribuzin (Correia et al., 2010; Ramesh and Sundari, 2006), diuron (Judice Wilson et al., 2006; Gana et al., 2006), and pendimethalin (Bhullar et al., 2006, 2008a; Viator Blaine et al., 2002) have been reported to be effective and safe in sole sugarcane but some of these herbicides can be toxic to several dicot crops. In an intercropping system of sugarcane and Indian mustard (*Brassica juncea*), oxyfluorfen at 0.23 kg ha^{-1} was effective and safe to both the crops (Singh et al., 1997) but fluazifop-butyl was phytotoxic to sugarcane (Mehra et al., 1989). In sugarcane-mentha (*Mentha arvensis*) intercropping system, Bhullar et al. (2009) found that isoproturon, oxyfluorfen, pendimethalin and trifluralin were safe to both the crops. Previous research has shown that pendimethalin (Roshdy et al., 2008), alachlor (Shimi et al., 2007), fluchloralin and trifluralin (Chauhan et al., 2005; Singh and Agarwal, 2004) can be safely used in rapeseed and mustard crops. At present, information on the selectivity and efficacy of herbicides for weed control in autumn sugarcane intercropped with oilseed *Brassicas* is scarce and this is considered a serious knowledge gap. Therefore, the present study was conducted (a) to investigate the agronomic performance and profitability of intercropping combinations of sugarcane with oilseed rape (*Brassica napus*) and Indian mustard (*Brassica juncea*) relative to sole sugarcane and (b) to determine the effectiveness of different herbicides for weed control in oilseed rape and Indian mustard intercropped with autumn sugarcane.

2. Materials and methods

2.1. Description of the experiment

A field study was conducted during 2010–11 and 2011–12, under irrigated conditions, at the research farm of the Punjab Agricultural University, Ludhiana, India. The soil at the experimental site was loamy sand, pH (7.4) and EC (0.24 ds m^{-1}), low in organic carbon (0.38%) and available N (248.7 kg ha^{-1}) and medium in available P (15.5 kg ha^{-1}) and available K (162.4 kg ha^{-1}). The field capacity and permanent wilting point of 0–60 cm rhizosphere were 11.84 cm and 2.95 cm, respectively. Hence, the available water in the 0–60 cm of soil profile worked out to be 8.89 cm. The average bulk density of the soil was 1.60 g cm^{-3}.The weather parameters during 2010–11 (first) and 2011–12 (second) cropping seasons are shown in Fig. 1.The first and second cropping seasons experienced 1333.6 mm and 508.3 mm rainfall, respectively. The mean monthly relative humidity ranged between 42 and 84% and 33–80%, total monthly pan evaporation varied between 37.2 and 227 mm and 42.6–320.2 mm, during 2010–11 and 2011–12, respectively. The study was established in a split-plot design with four replications. The study consisted of three cropping systems (sole sugarcane, sugarcane–oilseed rape (*B. napus*) and sugarcane-Indian mustard (*B. juncea*) in the main-plots and six weed control treatments (pendimethalin at 0.562 kg and 0.75 kg ha^{-1}, alachlor at 1.25 kg and 1.875 kg ha^{-1}, hand weeding (30 and 60 days after sowing (DAS) and weedy check) in the sub-plots. The area of each subplot was 22.5 m^2. The sugarcane (cv. CoJ 85; early maturing, average ratooner cultivar with high sugar content) was planted in the second fortnight of October in both the seasons in 90 cm spaced furrows, using 50,000 three budded setts ha^{-1}.On the following day, one row of oilseed rape (cv. *Gobhi Sarson Canola* 6 (GSC 6); 145d, short stature and early maturing) and two rows of Indian mustard (cv. *Raya Ludhiana Canola* 1 (RLC 1); 152d, tall with profuse branching) were intercropped using 2.5 kg seed ha^{-1} in the inter-row space of sugarcane. The local recommendation for row spacing is 45 cm for oilseed rape and 30 cm for Indian mustard. Therefore, only one row of oilseed rape was seeded in the middle of two cane rows and two 30-cm spaced rows of Indian mustard were seeded between two rows of cane. The sugarcane and intercrops were sown in a moist bed after heavy pre-sowing irrigation (10 cm), and subsequent irrigations were applied as per the local recommendation for the intercrops. The first post-irrigation was applied 3–4 weeks after sowing of intercrops, the second irrigation was applied in early January and third (last) irrigation was applied in second fortnight of February. After harvesting of the intercrops, the sugarcane crop was irrigated at 7–10 days interval from April–June (dry and hot months); the frequency of irrigation was adjusted according to rainfall from July–September (the south–west monsoon season), and at monthly interval in October–November. The sole sugarcane crop was supplied with 225 kg N ha^{-1}; the intercrops were supplied with additional 50 kg N and 25 kg P_2O_5 ha^{-1}. Herbicide treatments were applied using flat fan nozzle boom with an output of 500 L ha^{-1} on the day of sowing of the intercrops. Oilseed rape and Indian mustard were harvested manually in the second fortnight of March and in the first fortnight of April, respectively. All treatments were hand-weeded after the harvest of intercrops, which occurred just prior to the start of the active tillering phase of sugarcane. The sugarcane crop was harvested in December in both the seasons (15 months after planting). The ratoon crop was not taken in the present study as harvesting of autumn sugarcane coincides with severe winter season (mid-December to mid-January) and low temperature and frost results into poor sprouting of sugarcane buds and poor ratoon yields. The ratoons in north India are more popular in spring and summer sown crops in which harvesting starts close to the onset of spring season and good ratoon cane yields can be achieved. The study was conducted in adjoining fields during both the years, as the optimum sowing time of autumn sugarcane falls in October and the crop is harvested in December in the succeeding year.

2.2. Data collection

Weed density and biomass samples (above ground parts) were taken from two representative locations within each plot by using a quadrat of 50 cm × 50 cm at 35, 70 and 105 days after sowing (DAS) of the intercrops. Weed density was recorded by species and their total biomass was recorded after drying the samples at 70 °C in an oven for 72 h. The growth and yield parameters of the intercrops were recorded from 10 representative plants in each plot. Crop yields were recorded from 13.5 m^2 area from the centre rows in each plot. Cane equivalent yield was calculated by multiplying the average market price of intercrops with their seed yield and dividing by sugarcane price. Monetary returns (in USD) were calculated by taking average yearly exchange rate of USD and INR for 2011 (INR 46.6 per USD) and 2012 (INR 53.4 per USD). Benefit cost ratio (B:C) was derived by dividing the profit of each cropping system by the costs incurred to produce that profit, and was used for comparing the profitability of each intercropping system as compared to sole sugarcane, and of different weed control treatments.