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Management of weeds in sugarcane-wheat intercropping system in sub-tropical India

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ABSTRACT

Sugarcane being a widely spaced crop offers considerable space for cultivation of short duration intercrop. In sub-tropical India, sugarcane planted in autumn accounts for higher productivity due to extended period (approximately 12–16 months) of vegetative growth, but its feasibility is only possible if some intercrop especially wheat in *Rabi* season is sown as it can help farmer in generating additional income in midway of sugarcane season. Two rows of wheat has already been recommended in the north – western India, but the success was marred due to lack of suitable weed control methods in sugarcane – wheat intercropping system. Twelve weed control treatments including ten applications with post-emergent herbicides *i.e.* sulfosulfuron 25 g/ha and 37.5 g/ha, pinoxaden 50 g/ha and 75 g/ha, readymade blend of sulfosulfuron + metsulfuron 30 g/ha and 45 g/ha, readymade blend of mesosulfuron + iodosulfuron 14.4 g/ha and 21.6 g/ha, metsulfuron 5 g/ha , carfentrazone-ethyl 20 g/ha, a weed free treatment with two hoeings at 3 and 6 weeks after sowing wheat (WASW) and an unweeded control (no hoeing and no herbicide application) were evaluated for three years from 2008-09 to 2010-11 in randomized block design with three replications. The objective of the experiment was to identify the best possible method of weed control for maximizing the productivity of sugarcane wheat intercropping system. All the chemical and cultural weed control treatments including the application of herbicides and manual hoeings suppressed the weeds efficiently as compared to the unweeded control. Among the herbicidal spray, application of sulfosulfuron 25 g and 37.5 g/ha recorded the lowest pooled dry matter of weeds and thus exhibited the highest weed control efficiency (mean of three years) (61.2% and 63.5%, respectively). The highest pooled cane equivalent yield of 92.7 t/ha was recorded with sulfosulfuron + metsulfuron 30 g/ha. Application of any herbicide at a higher dose than normal, could not supplement additional millable canes and sugarcane yield. Application of readymade blends of sulfosulfuron + metsulfuron 30 g/ha and mesosulfuron + iodosulfuron 21.6 g/ha produced pooled intercropped wheat yield of 3.41 and 3.49 t/ha which surpassed the 3.35 t/ ha of wheat yield achieved with two manual hoeings at 3 and 6 WASW. The cane quality was not affected by application of any herbicide.

Key words: Herbicides, Intercropping system, Sugarcane, Sulfosulfuron, Weed control, Wheat

Severe decline in water table, degradation of soil and environment in the irrigated trans-gangetic tracts of sub-tropical India due to the paddy – wheat monoculture has forced the researchers to think of an optimal cropping rotation for the region. Some opine that sugarcane alongwith an intercrop could be a potential system which can match (or even surpass) the minimum support price (MSP) of wheat/rice offered by the government and thus can help the farmers in sustaining their current income level. Sugarcane in sub-tropical part of India is being sown twice a year, one as spring cane in the month of February – March and the other as autumn cane during the month of September – October. Autumn sugarcane takes around 12 to 14 months on account of extended growth period due to longer duration for tiller production (Rana *et al.* 2006) while the spring sugarcane takes 10-11 months to mature. Consequently, in a subsistence farming situation a farmer can not afford to loose the income from a *Rabi* crop, as larger gap in income flow may ruin his domestic economy. Hence, in intensively cultivated areas, introducing an intercrop within the main crop is one of the most promising options for crop diversification and narrowing the gap in income generation i.e. once a year from sugarcane to twice a year with an additional intercrop.

Intercropping in sugarcane has been recognized as a potential system for augmenting the productivity over space and time. The inter row distance for cultivating autumn sugarcane ranged from 0.9 m to 1.5 m in trans-gangetic plains and inclusion of intercrops in these inter row spaces offers a better

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scope for increasing the total productivity and income. There is generally a trend toward higher productivity in an intercropping system. Even in areas where yield of the companion crop was substantially reduced, the total yield was greater (Aggarwal *et al.* 1992, Imam *et al.* 1990 and Bokhtiar *et al.* 1995). Autumn planting of sugarcane is more remunerative than spring sugarcane as after initial germination of autumn sugarcane, its growth slows down during winter months (Nov. to 1st week Feb.) allowing a farmer to easily cultivate a *Rabi* intercrop in the wider inter-row spaces. To increase the sustainable agricultural production system in India, intercropping in sugarcane with short duration crops enables the small and marginal farmers to harvest more economic returns on account of better utilization of land, labour, nutrients and irrigation water. Several crops like lentil, potato, peas, cabbage, onion, garlic, winter maize, urdbean, okra, mentha *etc*. are recommended as intercropping in autumn and spring planted sugarcane (Singh *et al.* 1986, Lal and Singh 2004, Jamuna *et al.* 2007, Tripathi and Lawande 2008). Benefits of intercropping legumes like soybean, sunhemp and cowpea in sugarcane improved the soil properties, sustain the sugarcane yield and increases the total productivity of the system (Khandagave 2010, Li *et al.* 2013, Jamuna *et al.* (2007).

Wheat being the staple food of the farmers in sub-tropical India gets better price and assured marketing and thus is the most economically viable and feasible intercrop during the *Rabi* season. As per the availability of inter row spaces between sugarcane, two rows of wheat as an intercrop balances the competition for resources and thus has already been recommended to step up the production of both the crops (PAU 2011). Still this practice is not popular among the farmers as the reduced intercultural operations in an intercropping system may sometimes lead to enhanced weed infestation.

Weed management in an intercropping system has always been an issue as concentrated efforts are required to provide weed-free environments at regular intervals to both main/base crop and component crop for attaining higher productivity levels (Shah 2011). Reductions in yield due to weeds, both in sole and intercropped sugarcane, have been estimated to vary from 26 to 75% (Patil *et al.* 1991; Srivastava *et al.* 2005). Manual and cultural weed-control measures are often rendered uncertain due to interference of rains. The use of the herbicides is, thus, the only resort as it offers a good scope for timely and adequate control of weeds.

The weed control recommendations made for sole sugarcane crop using atrazine and metribuzin (Singh and Kumar 2013) or even that used in ratoon crop using diuron (Kumar *et al.* 2014) may not hold good in an intercropping system due to operational and phyto-toxicity issues. It was in this context that the present investigations was undertaken to find out economically viable alternative weed management strategy for autumn sugarcane – wheat intercropping system. An intercropping of wheat in sugarcane coupled with effective weed-control measures may help the farming community to realize the potential yield of both wheat and sugarcane.

MATERIALS AND METHODS

The field experiment was conducted during 2008–2011 at Ladhowal farm of Punjab Agricultural University, Ludhiana which represents the Indo-Gangetic alluvial plains and is situated at 30^0 56' N latitude and 75^0 52' E longitudes with an altitude of 247 m above the mean sea level. The area is characterized by sub-tropical and semi-arid type of climate with hot and dry summer from April to June followed by hot and humid period during July to September and cold winters from November to January. The mean maximum and minimum temperatures show considerable fluctuations during different parts of the year. Summer temperature hovers around 38^0C and touches 45^0C with dry summer spells. Winter experiences frequent frosty spells especially in December and January and minimum temperature dips up to 0.5^0C. The average annual rainfall of Ludhiana is 733 mm (Kingra *et al.* 1996), the major portion of which (75%) is received during July to September. The soil of the experimental field during first and third cropping season was loamy sand with pH of 7.5 and EC of 0.22 dS/m , low in organic carbon (0.31%) and available N (188 kg/ha) medium in available Olsen's P (13.4 kg/ha) and exchangeable K (257 kg/ha) in the top 15 cm soil depth. During the 2^{nd} cropping season soil was sandy loam in texture, low in organic carbon (0.36%), medium in available phosphorus (18.5 kg/ha) and medium in exchangeable potassium (305 kg/ha). The total rainfall received during the first, second and the third cropping season were 961.3, 740.7 and 1315.4 mm respectively.

The experiment comprised of a total of twelve weed control treatments including ten applications with post-emergent herbicides already recommended in sole wheat *i.e.* sulfosulfuron 25 g/ha and 37.5 g/ha, pinoxaden 50 g/ha and 75 g/ha, readymade blend of sulfosulfuron + metsulfuron 30 g/ha and 45 g/ha, readymade blend of mesosulfuron + iodosulfuron 14.4 g/ha and 21.6 g/ha, metsulfuron 5 g/ha, carfentrazone-ethyl 20 g/ha, a weed free treatment with two hoeings at 3 and 6 weeks after sowing wheat (WASW) and an unweeded control (no hoeing and no herbicide application). The lower doses of herbicides are at recommended doses to sole wheat while the higher dose is one and half times over the recommended one with an objective to assess the visual symptoms of toxicity to sugarcane, if any. All the herbicides were sprayed at 4 – 5 WASW but after the application of first irrigation, assuring presence of sufficient moisture at the time of spray. These treatments were evaluated under randomized block design with three replications. Sugarcane variety '*CoJ 85*' was planted in rows 90 cm apart using 50,000 three budded setts per ha (approximately 85 qtls seed) in autumn season during the first week of Oct. over the three consecutive years. The wheat variety *PBW 550* was intercropped as dual rows 20 cm apart in between two rows of autumn sugarcane in the 1st fortnight of Nov. after a pre sowing irrigation during all the three years of study. The gross plot size for sugarcane during first and third cropping season was 4.5 x 5.0 m = 22.5 m^2 while it was 5.4 x 5.0 m = 27.0 m^2 during the second cropping season. The plot size for wheat as intercrop during first and third cropping season was 3.6 x 5.0 m = 18.0 m^2 and during the second cropping season was 4.5 x 5.0 m = 22.5 m^2.

Recommended doses of fertilizers were applied to sugarcane (225 kg N/ha) and wheat (N: P_2O_5 : K_2O 25 : 12 : 12 kg/ha). N was applied in three equal splits to sugarcane (at planting, in end March and last dose in end April after the harvest of wheat alongside cane rows) and in two splits to wheat (half at sowing and half after first irrigation). Full dose of P and K fertilizers were applied at sowing only. All the other cultural operations were followed as per recommended package of practices to raise a healthy sugarcane and wheat crop (PAU 2011). Herbicides were applied 35-40 days after intercropping wheat using knapsack sprayer fitted with flat fan nozzle using a spray volume of 375 lts/ha. Sugarcane was harvested close to the ground manually from the central rows of each plot during second fortnight of following November in all the three planting seasons. Wheat was harvested in the first fortnight of April during all the three cropping seasons and was threshed manually within the plots.

Data collection and analysis

The weed count and biomass of prevalent weed flora during *Rabi* season was assessed one month after spray of herbicides by using three random samples from a quadrat of 0.25 m^2. The fresh sample of weeds so obtained from that quadrat were kept in hot air oven at 70^0C (till constant weight is recorded) for determining weed biomass and weed control efficiency. The weed control efficiency (WCE) was calculated using standard formula

Total yield of intercrop was recorded from the central rows of whole plot. Total number of sugarcane shoots were recorded at maximum tillering stage in June, two months after harvesting wheat. Five millable canes were randomly taken from the plot at sugarcane harvest and observations on yield attributes (cane length, internodes, millable canes, and single cane weight) and juice quality parameters (brix, Pol and purity) were recorded. Juice quality was determined following the procedure described by Gupta (1977). Sucrose per cent was determined as per Chen (1985). Cane equivalent yield was calculated by multiplying the average existing market price of wheat with its yield and dividing it by the price of sugarcane. Monetary returns are presented using the market prices of wheat as ` 10000, 11000, and 12850 per tonne while for sugarcane as ` 1800, 2000 and 2300 per tonne during 2008-09, 2009-10 and 2010-11 respectively. Benefit cost ratio (B:C) was derived by dividing the gross returns from the intercropping system by the total cost of production and was used for comparing the profitability of different weed control treatments over the unweeded control treatment. The sugar recovery as commercial cane sugar (CCS %) was determined as per Ahmed *et al.* (1998). Analysis of variance (ANOVA) on the collected data were calculated in a RCBD to test the level of significance at $P < 5.0\%$. Weed count and weed biomass data were square root transformed before performing ANOVA to normalize the distribution of residuals.

RESULTS AND DISCUSSION

Weed flora

The weed flora that emerged in the initial stages of autumn sugarcane was altogether different than those emerged in spring planted sugarcane in sub-tropical India. The dominant weeds, which were prevalent during the three *Rabi* seasons after the sugarcane and wheat planting were *Phalaris minor, Chenopodium album, Anagallis arvensis, Cyperus rotundus, Euphorbia simplex, Convolvulus arvensis, Rumex dentatus, Vicia sativa, Melilotus alba, Trigonella polycerata, Lepidium sativum, Fumaria parviflora,* and *Spergula arvensis.*

Weed density

The weed density observed 30-40 days after the herbicide spray in wheat intercropped in sugarcane crop differed significantly during all the three consecutive years of experimentation (2008-09, 2009-10 and 2010-11). The results in (**Table 1**) revealed that different weed control treatments recorded significantly lower weed density than the unweeded control. Among the weed control treatments, the lowest weed density or the best control was found with the post-emergence spray of mesosulfuron + iodosulfuron 14.4 g/ha in the first two experimental years and it was significantly better than the unweeded control. The pooled data too indicated excellent control by mesosulfuron + iodosulfuron 14.4 g/ha. Sulfosulfuron + metsulfuron 30 and 45 g/ha, sulfosulfuron 25 and 37.5 g/ha, pinoxaden 50 and 75 g/ha, carfentrazone-ethyl 20 g/ha and metsulfuron-methyl 5 g/ha too significantly lowered the weed density as compared to unweeded control but were statistically at par to two manual hoeings given at 3 and 6 WASW in all the years of study. The pooled data too followed the similar trend except for the application of mesosulfuron + iodosulfuron 14.4 g/ha which proved significantly better in restricting the weed density as compared to the metsulfuron-methyl 5.0 g/ha (**Table 1**). Some of the annual grasses might have escaped the killing action as metsulfuron-methyl is an organic compound classified as a sulfonylurea herbicide, which kills broad-leaf weeds and some annual grasses (Arnold *et al.* 2002). Using herbicides at higher dose (1.5 times the normal) could not ascertain any additional benefit in reducing the weed density.

Weed biomass

The minimum dry matter of weeds over the three years when pooled together were observed in treatment where two manual hoeings were given at 3 and 6 WASW. Post-emergence spray of sulfosulfuron 25 g and 37.5 g/ha, sulfosulfuron+ metsulfuron 30 g and 45 g/ha, metsulfuron-methyl 5 g/ha and carfentrazone-ethyl 20 g/ha reduced the dry matter of weeds at par to that observed under two hoeings at 3 and 6 WASW. But mesosulfuron + iodosulfuron 14.4 g and 21.6 g/ha as well as pinoxaden 50 g/ha recorded significantly higher weed dry matter than that obtained with two manual hoeings at 3 and 6 WASW (pooled data in **Table 1**). The appearance of new flush of weeds after a fortnight of application of these herbicides at the time of recording data might have increased the dry matter of weeds indicating lower residual effect after their spray while in case of manual hoeing, the weeds are cut 4-5 cm below the soil surface allowing them to emerge a little late after the completion of manual hoeing. All the chemical and cultural weed control treatments including the application of herbicides and manual hoeings proved significantly much better in effectively reducing the dry matter of weeds as compared to the unweeded control. Among the herbicidal spray, the lowest pooled dry matter of weeds were recorded when sulfosulfuron was applied 37.5 g/ha. The higher

Table 1. Weed density, dry matter of weeds and weed control efficiency as influenced by different weed control treatments

Treatment	Weed density/m^2				Weed biomass (g/m^2)				Weed control efficiency (%)			
	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Mean
Sulfosulfuron 25 g/ha	8.65(74.7)	7.59(58.7)	8.05(64.0)	8.17(65.8)	7.51(55.9)	7.67(58.8)	8.45(71.3)	7.91(62.0)	71.8	59.2	46.4	61.2
Sulfosulfuron 37.5 g/ha	9.05(81.3)	7.49(57.3)	8.65(74.7)	8.45(71.1)	8.10(65.0)	6.57(42.7)	8.11(65.7)	7.64(57.8)	66.7	70.7	50.5	63.5
Pinoxaden 50 g/ha	9.30(86.7)	7.45(56.0)	7.81(61.3)	8.29(68.0)	8.34(69.2)	9.01(80.2)	9.25(84.7)	8.89(78.0)	65.5	44.0	37.4	51.6
Pinoxaden 75 g/ha	8.51(72.0)	6.70(45.3)	8.97(80.0)	8.16(65.8)	8.08(65.4)	7.84(61.8)	8.77(76.7)	8.30(68.0)	66.4	56.6	42.3	57.5
Sulfosulfuron + metsulfuron 30 g/ha	8.64(74.7)	7.97(62.7)	8.02(64.0)	8.25(67.1)	8.25(67.7)	7.51(55.8)	8.39(70.7)	8.08(64.8)	65.4	62.1	50.1	60.3
Sulfosulfuron + metsulfuron 45 g/ha	9.37(88.0)	7.55(56.0)	8.19(66.7)	8.43(70.2)	8.60(73.3)	7.43(56.3)	8.05(65.3)	8.10(65.0)	63.2	58.2	54.2	59.5
Mesosulfuron + iodosulfuron 14.4 g/ha	8.04(64.0)	6.46(41.3)	8.27(68.0)	7.65(57.8)	8.17(66.7)	9.03(81.2)	9.43(88.0)	8.90(78.6)	66.2	40.8	35.9	50.7
Mesosulfuron + iodosulfuron 21.6 g/ha	8.95(80.0)	6.74(45.3)	8.53(72.0)	8.16(65.8)	8.48(71.0)	8.84(77.4)	8.87(78.0)	8.74(75.5)	64.1	45.3	42.8	53.1
Metsulfuron-methyl 5 g/ha	9.13(82.7)	7.79(60.0)	9.32(86.7)	8.79(76.4)	7.68(58.2)	8.52(73.7)	8.21(67.7)	8.20(66.5)	70.2	46.6	52.1	58.1
Carfentrazone-ethyl 20 g/ha	8.73(76.0)	8.13(66.7)	7.85(61.3)	8.31(68.0)	8.12(65.5)	8.29(69.2)	8.78(76.7)	8.45(70.5)	66.5	50.1	42.5	56.0
Two hoeings at 3 and 6 WASW	8.48(72.0)	7.46(54.7)	8.75(76.0)	8.27(67.5)	7.11(49.7)	7.89(61.8)	7.48(55.7)	7.51(55.7)	75.0	57.8	58.6	65.6
Unweeded control (weedy check)	14.19(201)	13.59(184)	13.86(193)	13.92(192)	14.11(198)	12.16(148)	11.83(139)	12.76(162)	-	-	-	-
LSD (p=0.05)	1.80	2.01	1.88	0.87	1.55	2.10	1.92	1.12	-	-	-	-

Yr 1, Yr 2, and Yr 3 represents 2008-09, 2009-10 and 2010-11 respectively. WASW – Weeks after sowing wheat

Values of weed density and drymatter are transformed to square root while those in parentheses are the original values efficacy of sulfosulfuron towards better control of broad-leaf weeds might be the cause in registering the lowest ever recorded dry matter of weeds in the treated plot. Post-emergence application of all the herbicides irrespective of the dose in any individual year reduced the dry matter at par to each other except for the significant dominance of sulfosulfuron 37.5 g/ha over mesosulfuron + iodosulfuron 14.4 g and 21.6 g/ha as well as over pinoxaden 50 g/ha in the second year of study. The presence of higher number of broad-leaf weeds and its efficient control by sulfosulfuron 37.5 g/ha in the corresponding year might have led to such pronounced effect. Moreover, the higher and normal dose of any herbicide reduces the dry matter of weeds in a statistically similar fashion.

Weed control efficiency

The weed control efficiency among the weed management practices ranged from 63.2% to 75.0% in 2008-09, 40.8 – 70.7% in 2009-10 and 35.9 – 58.6% in 2011-12 (**Table 1**). The highest weed control efficiency of 65.6% (mean of three years) was obtained in treatment given two hoeings at 3 and 6 WASW. Among the herbicides, the maximum weed control efficiency (mean of three years) was exhibited by the application of sulfosulfuron 25 g and 37.5 g/ha (61.2% and 63.5%, respectively) followed by post-emergence application of sulfosulfuron + metsulfuron 30 g and 45 g/ha (60.3% and 59.5%, respectively).

Growth of sugarcane

Shoots of sugarcane form a bunch and it ultimately determines the millable canes. Unchecked growth of weeds in weedy check treatment drastically reduced the shoots of sugarcane and significantly recorded the minimum number in all the years of the study. The pooled data too followed similar trend (**Table 2**). Post-emergence application of herbicides at tillering stage of intercropped wheat did not affect the shoot number of sugarcane and recorded shoots at par to those obtained under two hoeings at 3 and 6 WASW over three years of experiment. The other growth parameters like internodes per cane, single cane weight and height of canes recorded at maturity were found to be least affected by the application of herbicides or manual hoeings as their values were at par to the unweeded check (**Table 2**). The pooled data for all the growth parameters of sugarcane also showed similar effect.

Millable canes and cane yield

Tolerance of sugarcane to different post-emergent herbicides applied to intercropped wheat during the *Rabi* season has lead to the production of millable canes and cane yield, statistically at par to that obtained under two manual hoeings given at 3 and 6 WASW. This was reflected by the statistically similar data in the pooled and individual years of study. But surely all the chemical and cultural control measures produced significantly better millable canes

Table 2. Growth components of sugarcane as influenced by different weed control treatments

Treatment	Shoots (000/ha)				Internodes per cane				Single cane wt. (g)				Height of canes (cm)			
	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled
Sulfosulfuron 25 g/ha	175.3	158.2	160.1	164.5	16.3	14.6	15.1	15.3	816.5	809.1	827.3	817.6	192.9	167.7	172.5	177.7
Sulfosulfuron 37.5 g/ha	183.2	153.3	159.1	165.2	15.4	15.8	15.2	15.5	778.3	856.5	834.8	823.2	196.7	177.8	178.4	184.2
Pinoxaden 50 g/ha	183.2	145.7	150.1	159.7	15.2	14.4	15.3	15.0	804.4	860.1	810.3	824.9	205.0	168.7	180.8	184.8
Pinoxaden 75 g/ha	170.6	150.6	154.9	158.6	15.3	14.9	14.8	14.9	770.8	846.5	868.8	828.7	192.5	163.0	177.5	177.6
Sulfosulfuron + metsulfuron 30g/ha	180.5	150.8	162.4	167.3	14.7	14.4	13.9	14.3	814.5	883.8	860.1	852.8	206.3	175.3	182.1	187.9
Sulfosulfuron + metsulfuron 45g/ha	179.2	148.9	161.7	163.2	14.4	14.2	15.1	14.6	816.3	810.2	856.8	827.7	192.1	165.3	176.7	178.0
Mesosulfuron + iodosulfuron 14.4 g/ha	180.2	155.4	153.0	162.9	15.1	15.5	15.4	15.3	780.3	881.9	811.2	824.5	194.6	168.2	180.0	181.0
Mesosulfuron + Iodosulfuron 21.6 g/ha	189.8	142.9	154.9	162.5	14.4	14.8	14.6	14.6	882.4	920.9	735.2	846.2	194.5	172.6	191.3	186.1
Metsulfuron-methyl 5 g/ha	185.4	157.2	149.7	164.1	14.3	14.5	15.6	14.8	916.2	792.0	790.5	832.9	190.0	166.0	184.6	180.2
Carfentrazone-ethyl 20 g/ha	179.6	141.6	158.2	159.8	15.2	14.3	15.1	14.9	783.4	964.8	867.4	871.9	197.1	164.8	179.1	180.3
Two Hoeings at 3 and 6 WASW	186.3	144.1	154.0	161.4	14.9	14.3	13.8	14.3	820.1	906.3	805.2	843.8	185.8	170.9	185.9	180.9
Unweeded Control (weedy check)	126.4	122.3	115.9	121.5	15.4	14.9	15.2	15.1	789.2	873.4	831.2	831.3	185.4	161.3	168.7	171.8
LSD (p=0.05)	24.0	19.2	23.3	12.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Yr 1, Yr 2, and Yr 3 represents 2008-09, 2009-10 and 2010-11 respectively. WASW – Weeks after sowing wheat , NS – Non-significant and cane yield in individual years as well as when pooled, than the unweeded control (**Table 3**). The highest pooled cane yield of 74.0 t/ha was recorded with sulfosulfuron + metsulfuron 30 g/ha and similar results were also reflected in the individual years of study. The increase in pooled cane yield with different weed control treatments ranged from 32.5 - 45.7% over the unweeded control. The data also indicated that application of a herbicide at a higher dose than normal, could not supplement the millable canes and the sugarcane yield.

Wheat yield

Post-emergence herbicide application at variable rates helped in increasing the yield levels of intercropped wheat over the unweeded control treatment in all the years of study. Sulfosulfuron 25 g and 37.5 g/ha, sulfosulfuron + metsulfuron 30 g/ha, mesosulfuron + iodosulfuron 21.6 g/ha, carfentrazone-ethyl 20 g/ha and two hoeings (at 3 and 6 WASW) significantly increased the yield over the unweeded control in all the years of study. As per the pooled mean, all the herbicides irrespective of their application rates being at par to each other produced significantly better wheat yield ranging from 38.8 to 59.4% than the unweeded control (**Table 3**), but the application of sulfosulfuron + metsulfuron 30 g/ha, and mesosulfuron + iodosulfuron 21.6 g/ha was so pronounced that the intercropped wheat yield attained as high as 3.41 and 3.49 t/ha respectively surpassing even the treatment where two manual hoeings were given at 3 and 6 WASW (3.35 t/ha).

Cane equivalent yield

All the weed control treatments including the application of herbicides at variable rates and the weed free treatment of two hoeings at 3 and 6 WASW increased the cane equivalent yield significantly over the unweeded control in all the years of study. The pooled mean showed that the increase in cane equivalent yield with the weed control treatments ranged from 34.7% with pinoxaden 75 g/ha to 47.6% with the post emergence application of sulfosulfuron + metsulfuron 30 g/ha. Application of sulfosulfuron + metsulfuron 30 g/ha recorded maximum cane equivalent yield ranging from 86.8 to 96.5 t/ha in the individual years and the same effect was reflected in pooled mean (**Table 3**). All the herbicides when applied at variable doses produced statistically similar cane equivalent yield to each other as well as to the weed free treatment of two manual hoeings at 3 and 6 WASW. The results also indicated that the application of any herbicide in sugarcane wheat intercropping system should be made at the dose recommended in sole wheat crop as differences with it's application at higher dose was statistically at par.

Cane quality

Cane quality worked out in terms of PoL (%) and commercial cane sugar (%) (**Table 4**) registered non-significant effect between the treatments of weed control and the unweeded check. The per cent sucrose represented in terms of PoL % as well as CCS % is not affected by variable doses of herbicides indicating the quality to be a function of some other factors like enzymes and nutrition and not linked to the effect of weed control. Kumar *et al.* (2014) also reported non-significant results on quality aspects of sugarcane due to different weed control treatments.

Sugar yield

Sugar yield is a function of per cent CCS and the cane yield. So variation in sugarcane yield levels with the different application rates of herbicides or manual

Table 3. Yield components of sugarcane and wheat as influenced by different weed control treatments

Treatment	Millable canes (t/ha)				Cane yield (t/ha)				Wheat yield (t/ha)				Cane equivalent yield (t/ha)			
	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled	Yr 1	Yr 2	Yr 3	Pooled
Sulfosulfuron 25 g/ha	89.3	79.0	94.3	87.5	71.7	63.3	77.5	70.8	3.68	3.15	3.18	3.34	92.0	80.7	95.0	89.2
Sulfosulfuron 37.5 g/ha	85.3	77.1	90.3	84.3	65.5	66.0	74.6	68.7	3.35	3.29	3.29	3.31	84.0	84.1	92.7	86.9
Pinoxaden 50 g/ha	85.6	76.0	90.2	83.9	68.7	65.4	73.1	69.1	3.03	3.39	3.21	3.21	85.4	84.0	90.7	86.7
Pinoxaden 75 g/ha	86.4	73.1	85.8	81.8	66.0	61.8	74.1	67.3	3.48	2.96	2.99	3.14	85.2	78.1	90.6	84.6
Sulfosulfuron + metsulfuron 30g/ha	93.1	78.2	91.0	87.4	75.1	68.9	78.0	74.0	3.59	3.26	3.36	3.41	94.8	86.8	96.5	92.7
Sulfosulfuron + metsulfuron 45 g/ha	87.8	79.6	88.7	85.3	70.3	64.0	76.1	70.1	3.04	3.45	3.50	3.33	87.0	83.0	95.3	88.4
Mesosulfuron + iodosulfuron 14.4 g/ha	93.1	71.1	87.1	83.8	72.1	61.6	70.4	68.0	2.99	3.14	3.54	3.22	88.5	78.8	89.9	85.7
Mesosulfuron + iodosulfuron 21.6 g/ha	84.6	72.0	97.6	84.7	74.7	66.0	71.4	70.7	3.64	3.37	3.45	3.49	94.7	84.5	90.4	89.9
Metsulfuron-methyl 5 g/ha	80.0	81.3	89.1	83.5	73.0	64.7	69.7	69.1	3.10	3.20	2.81	3.04	90.0	82.3	85.2	85.8
Carfentrazone-ethyl 20 g/ha	87.8	68.7	87.8	81.4	68.3	66.2	76.1	70.2	3.17	2.92	3.32	3.14	85.7	82.3	94.4	87.4
Two hoeings at 3 and 6 WASW	85.2	69.5	87.3	80.7	69.9	62.9	70.1	67.6	3.90	3.04	3.11	3.35	91.4	79.6	87.1	86.0
Unweeded control (weedy check)	64.7	51.5	68.5	61.5	50.9	44.7	56.8	50.8	2.32	2.06	2.18	2.19	63.7	56.0	68.8	62.8
LSD (p=0.05)	14.2	13.5	12.3	7.8	12.3	11.2	10.8	8.0	0.82	0.72	0.71	0.47	12.5	11.6	11.0	8.4

Yr 1, Yr 2, and Yr 3 represents 2008-09, 2009-10 and 2010-11 respectively. WASW – Weeks after sowing wheat

Prices of sugarcane and wheat for calculating cane equivalent yield were taken as ` 1800, 2000 and 2300/- per tonne for sugarcane and ` 10000, 11000 and 12850/- per tonne for wheat during 2008-09, 2009-10 and 2010-11 respectively hoeings significantly changed the sugar yield. All the herbicides when applied at recommended or 1.5 times the recommended dose produced the sugar yield at par to the two manual hoeings at 3 and 6 WASW but produced significantly better sugar yield than the unweeded control. The higher doses of applied herbicides in sugarcane – wheat intercropping system statistically could not show any additional advantage in improving the sugar yield.

Table 4. Quality aspects of sugarcane as influenced by different weed control treatments

Treatment	PoL (%)			CCS (%)			Sugar yield (t/ha)		
	Yr 1	Yr 2	Pooled	Yr 1	Yr 2	Pooled	Yr 1	Yr 2	Pooled
Sulfosulfuron 25 g/ha	16.80	18.06	17.43	11.50	12.40	11.95	8.3	7.8	8.0
Sulfosulfuron 37.5 g/ha	16.63	18.45	17.54	11.39	12.65	12.02	7.5	8.4	7.9
Pinoxaden 50 g/ha	16.43	18.44	17.44	11.17	12.75	11.96	7.7	8.3	8.0
Pinoxaden 75 g/ha	16.96	18.73	17.85	11.62	12.98	12.30	7.7	8.0	7.9
Sulfosulfuron + metsulfuron 30 g/ha	17.33	17.66	17.50	11.86	12.16	12.01	8.9	8.4	8.6
Sulfosulfuron + metsulfuron 45 g/ha	16.97	18.17	17.57	11.64	12.57	12.11	8.2	8.1	8.1
Mesosulfuron + iodosulfuron 14.4 g/ha	16.26	18.16	17.21	11.10	12.58	11.84	8.0	7.8	7.9
Mesosulfuron + iodosulfuron 21.6 g/ha	17.41	18.92	18.16	11.93	13.20	12.56	8.9	8.8	8.8
Metsulfuron-methyl 5 g/ha	16.45	18.32	17.39	11.21	12.69	11.95	8.2	8.2	8.2
Carfentrazone-ethyl 20 g/ha	17.45	18.87	18.16	12.04	13.11	12.57	8.2	8.6	8.4
Two hoeings at 3 and 6 WASW	18.02	17.33	17.68	12.40	11.86	12.13	8.7	7.5	8.1
Unweeded control (weedy check)	16.99	17.14	17.07	11.68	11.69	11.69	6.0	5.2	5.6
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	1.45	NS	1.3

Yr 1 and Yr 2 represents 2008-09 and 2009-10 respectively. WASW – Weeks after sowing wheat CCS – commercial cane sugar

Table 5. Economics of different weed control treatments in sugarcane – wheat intercropping system

Treatment	Total cost of cultivation (x10^3 `)				Gross returns (x10^3 `)			
	Yr 1	Yr 2	Yr 3	Average	Yr 1	Yr 2	Yr 3	Mean
Sulfosulfuron 25 g/ha	95.28	103.61	117.39	105.43	165.60	161.40	218.50	181.83
Sulfosulfuron 37.5 g/ha	95.82	104.12	117.88	105.94	151.20	168.20	213.21	177.54
Pinoxaden 50 g/ha	95.81	104.13	117.92	105.95	153.72	168.00	208.61	176.78
Pinoxaden 75 g/ha	96.61	104.90	118.67	106.73	153.36	156.20	208.38	172.65
Sulfosulfuron + metsulfuron 30 g/ha	95.23	103.56	117.37	105.38	170.64	173.60	221.95	188.73
Sulfosulfuron + metsulfuron 45 g/ha	95.74	104.04	117.84	105.88	156.60	166.00	219.19	180.60
Mesosulfuron + iodosulfuron 14.4 g/ha	95.52	103.86	117.67	105.68	159.30	157.60	206.77	174.56
Mesosulfuron + iodosulfuron 21.6 g/ha	96.17	104.49	118.29	106.32	170.46	169.00	207.92	182.46
Metsulfuron-methyl 5 g/ha	94.60	102.93	116.73	104.75	162.00	164.60	195.96	174.19
Carfentrazone-ethyl 20 g/ha	94.69	103.03	116.85	104.86	154.26	164.60	217.12	178.66
Two hoeings at 3 and 6 WASW	98.70	107.73	123.62	110.02	164.52	159.20	200.33	174.68
Unweeded control (weedy check)	94.20	102.58	116.42	104.40	114.66	112.00	158.24	128.30

Yr 1, Yr 2, and Yr 3 represents 2008-09, 2009-10 and 2010-11 respectively. WASW – Weeks after sowing wheat

Prices of sugarcane were taken as ` 1800, 2000, 2300 per ton during 2008-09, 2009-10 and 2010-11 respectively

Table 6. Net returns and B:C of different weed control treatments followed in sugarcane – wheat intercropping system

Treatment	Net return (x10^3 `)				Benefit : Cost			
	Yr 1	Yr 2	Yr 3	Average	Yr 1	Yr 2	Yr 3	Mean
Sulfosulfuron 25 g/ha	70.32	57.79	101.11	76.41	1.74	1.56	1.86	1.72
Sulfosulfuron 37.5 g/ha	55.38	64.08	95.33	71.60	1.58	1.62	1.81	1.67
Pinoxaden 50 g/ha	57.91	63.87	90.69	70.82	1.60	1.61	1.77	1.66
Pinoxaden 75 g/ha	56.75	51.30	89.71	65.92	1.59	1.49	1.76	1.61
Sulfosulfuron + metsulfuron 30 g/ha	75.41	70.04	104.58	83.34	1.79	1.68	1.89	1.79
Sulfosulfuron + metsulfuron 45 g/ha	60.86	61.95	101.34	74.72	1.64	1.60	1.86	1.70
Mesosulfuron + iodosulfuron 14.4 g/ha	63.78	53.74	89.10	68.87	1.67	1.52	1.76	1.65
Mesosulfuron + iodosulfuron 21.6 g/ha	74.29	64.50	89.63	76.14	1.77	1.62	1.76	1.72
Metsulfuron-methyl 5 g/ha	67.40	61.67	79.23	69.43	1.71	1.60	1.68	1.66
Carfentrazone-ethyl 20 g/ha	59.57	61.56	100.27	73.80	1.63	1.60	1.86	1.69
Two hoeings at 3 and 6 WASW	65.82	51.47	76.71	64.67	1.67	1.48	1.62	1.59
Unweeded control (weedy check)	20.46	9.42	41.82	23.90	1.22	1.09	1.36	1.22

Yr 1, Yr 2, and Yr 3 represents 2008-09, 2009-10 and 2010-11 respectively. WASW – Weeks after sowing wheat

Economics

Manual weed management by hoeings incur huge cost of labour which increases the total cost of cultivation and thus rendering it to be non-viable option as compared to herbicide application (**Table 5**). Application of sulfosulfuron + metsulfuron 30 g/ ha in wheat intercropped in sugarcane gave the highest net returns of ` 83344/- and a benefit cost ratio was 1.79 (**Table 6**). The next profitable alternative was use of sulfosulfuron 25 g/ha which lead to the net returns of ` 76407/- and a benefit cost ratio of 1.72. The similar benefit cost ratio was also obtained when mesosulfuron + iodosulfuron 21.6 g/ ha was applied to control weeds in sugarcane – wheat cropping system.

It was concluded that the productivity of intercropping of wheat in autumn sugarcane can be enhanced effectively by controlling *Rabi* weeds with the application of sulfosulfuron, sulfosulfuron + metsulfuron, mesosulfuron + iodosulfuron, metsulfuron-methyl, carfentrazone-ethyl, pinoxaden at a dose already recommended to wheat crop in sub-tropical part of India.

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