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Bioefficacy of herbicides and impact of different tillage practices on weed population dynamics in sweet corn (*Zea mays saccharata* L.) Under temperate conditions of western Himalayas

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Abstract
A field experiment was conducted at Faculty of Agriculture Wadura (SKUAST-K) during kharif 2020-2021 to investigate the effect of different herbicide combinations and tillage practices on weed population dynamics and productivity of sweet corn. The treatment comprised of two tillage practices (conventional and zero tillage) and different weed management methods including six herbicide treatment combinations *viz*., T_1 (Atrazine 1.0 kg ha^{-1} (PE) fb. mechanical weeding at 50 DAS), T_2 (Pendimethalin 1.0 kg ha^{-1} (PE) fb. mechanical weeding at 50 DAS), T_3 (Atrazine + Pendimethalin (0.75 + 0.75 kg ha^{-1} (PE) fb. mechanical weeding at 50 DAS), T_4 (Tembotrione 120 g ha^{-1} (PoE) at 25 DAS, T5 (Atrazine 1.0 kg ha^{-1} (PE) fb. Tembotrione 120 g ha^{-1} (PoE) at 25 DAS, T_6 (Pendimethalin 1.0 kg ha^{-1} (PE) fb. Tembotrione @ 120 g ha^{-1} (PoE) at 25 DAS, T_7 Weed free (mechanical weeding at 15, 30, 45, 60 DAS) and T_8 (Weedy check). The experiment was laid out in split plot design with three replications. The soil of the experimental field was silty clay loam in texture, neutral in reaction with medium N (287 kg ha^{-1}) and P (12.75 kg ha^{-1}) and medium in K (187.0 kg ha^{-1}).Significant variation in weed density and weed dry matter accumulation was recorded in conventional tillage in comparison to the zero tillage. Study reveals that among different weed management methods significant reduction in weed density and weed dry matter accumulation was observed in weed free (T_7) followed by treatment T_5 which showed significant difference from rest of the treatments. Significantly, highest weed density and weed dry matter accumulation was found in weedy check (T_8). Two years experiment revealed that the efficient control of weeds in weed free plot resulted in highest green cob yield 207.27 q ha^{-1} and 222.27q ha^{-1}, respectively which was found at par with (T_5) 206.28 q ha^{-1} and 221.28 q ha^{-1}, respectively because of efficient control of weeds by atrazine 1.0 kg ha^{-1} given as pre-emergent followed by tembotrione 120 g ha^{-1} as PoE hebicide. Similarly conventional tillage resulted in highest green cob yield 187.97 q ha^{-1} and 202.97 q ha^{-1} over zero tillage 161.46 q ha^{-1} and 176.25 q ha^{-1}, respectively.

Keywords: Conventional tillage, zero tillage, weed management, atrazine, Pendimethalin, tembotrione, sweet corn, green cob yield

Introduction
Traditional tillage methods have long been used to raise key crops such as maize, but they are today considered to be labour and fuel intensive activities. As a result, switching from conventional to zero tillage would save energy while also conserving soil and water. Furthermore, zero tillage lowers the cost of field preparation (Singh *et al*., 2001) [17], and yield returns are comparable to, or even exceed, conventional tillage in some circumstances (Memon *et al*., 2012) [5]. Weeds inflict significant harm to maize crops, with losses ranging from 30 to 50 percent depending on the weed population. Weeds diminish crop yield by competing for light, water, nutrients, and carbon dioxide, cause harvesting problems, and raise crop production costs, depending on the type of weed flora, severity, and length of crop weed competition (Oerke, 2005) [8]. Maize yield losses range from 28 to 93 percent (Lal and Saini, 1985) [3] and even 100 percent (Patel *et al*., 2006) [10] due to unmanaged weed growth (Angiras and Singh, 1988; Karki *et al*., 2010) [1, 2] Due to rising labour costs and an insufficient availability of labour in a timely manner, it is required to develop less expensive weed control strategies using herbicides or herbicides in combination with other non-chemical approaches.

Because of the richness of nutrients, sweet corn (*Zea mays sacharata*), a specialty corn, is the new age super diet for health-conscious people (Ramachandrappa and Nanjjappa, 2006) [12]. Sweet corn has antioxidant properties, with special reference to its lutein content. Lutein reduces the risk of cataract and age-related macular degeneration (Landrum *et al.*, 1996) [4] and protects the eye from free radicals and near-to-UV blue light (Wenzel *et al.*, 2003) [8]. The nutritive value of sweet corn is comparable to several high priced vegetables like cauliflower, cabbage and French bean. Sweet corn (Zea mays saccharata) is a unique form of corn that can be eaten fresh or tinned. Sweet corn kernels are available in both fresh and processed versions. Cobs harvested at the milking stage are sold as "fresh produce," while those harvested at late-milk maturity of seed are used to make pickles and frozen dishes. Cobs are gathered at full ripeness of seed for flour, meal, and other uses. It is one of the most popular vegetables in countries such as the United States and Canada, and it is also gaining popularity in India and other Asian countries. Growers are rapidly transitioning to specialty corn production, such as sweet corn, due to low returns per unit area in standard maize. This tremendous potentiality can be seen not only in the domestic market, but also in the worldwide market. Furthermore, quality fodders (based on sweetness) generated after harvest may be sold, bringing in additional cash for the farmers because the cattle enjoy it. The sweet corn sector is growing due to rising domestic demand, export development, and import substitution. It is a desirable crop for farmers since it grows quickly and may be used in mechanical farming operations. The majority of sweet corn is cultivated for the processing industry and ends up on supermarket shelves as canned kernels, frozen cobs, and frozen kernels (Najeeb *et al*., 2011) [7]. Sweet corn requires a lot of input, therefore study on tillage requirement and herbicidal weed management are the need of an hour.

Materials and Methods

The current research was conducted during the (*kharif)* season of 2020-2021 at the Research Farm of the Division of Agronomy, Faculty of Agriculture and Regional Research Station, Wadura, SKUAST-K, Jammu and Kashmir (latitude 34° 172′ N, longitude 74° 332′) E and at an altitude of 1524 meters above mean sea level. The test site had a consistent topography and was well-drained. The experimental site is located in the temperate zone of the North Western Himalayas, where hot summers and very cold winters prevail. The average annual precipitation is 812 mm (average of the previous 30 years), with the majority of it falling as snow and rain from December to April. The maximum and minimum temperatures were 37.5 °C and 12.7 °C, 37.21 °C and 12.32 °C, respectively and the total precipitation amounted to 270 mm and 745mm, respectively during crop growth period of 2020-2021. The mean maximum and minimum relative humidity were 79.75% and 56.04%, 82.5% and 65.4% respectively during the cropping seasons of 2020 and 2021. The soil of the experimental field was silty-clay loam in texture, medium in organic carbon, available nitrogen, phosphorous and potassium with neutral pH and normal electrical conductivity (Table 1). The entire experimental field was divided into two main plots, one for conventional tillage and the other for zero tillage. To achieve the desired tilth, the field was prepared using one disc ploughing followed by two harrowing in traditional tillage. Manual replication borders, plot bunds, irrigation, and drainage channels were created in zero tillage, whereas non-selective translocated herbicide glyphosate was administered 10 days before seeding a crop in zero tillage. Sugar-75 seeds were sown at a rate of 10 kg ha^{-1} in rows 75 cm apart with a plant to plant spacing of 20 cm, resulting in a plant population of 66,666.66 plants ha^{-1}. In both traditional and zero-tillage systems, fertilizers were applied according to the recommendations. According to the treatment specifics, the various weed management strategies were divided into sub plots. During both years, the pre-emergent herbicides atrazine and pendimethalin were administered three days after sowing with a Knapsack sprayer equipped with a Flat fan Nozzle and a 600 liters ha^{-1} water volume. Post-emergent herbicides, on the other hand, are applied directly to the weeds being targeted. The soil was moist enough for effective herbicidal activity at the time of application.

Weed density (No m^{-2})

Weed density was calculated at various stages of growth by randomly throwing a 1 m^{-2} quadrant. Weeds within the quadrant were carefully cut at ground level, and the total number of weeds m^{-2} was counted. These weeds were further classified as grasses, sedges, and broad-leaved weeds.

Weed dry weight (g m^{-2})

The weed samples from 1m^2 quadrant in each plot were counted species wise at different growth stages *viz*., knee high, tasselling and maturity. These samples were oven dried at 60 °C temperature to a constant weight and dry weight was recorded and expressed in g m^{-2}.

Weed Index

Weed index is the measure of the efficiency of a particular treatment when compared with a weed free treatment. It is expressed as percentage of yield potential under weed free. More conveniently weed index is the per cent yield loss caused due to weeds as compared to unweeded (weedy check). Higher weed index mean greater loss. It is worked out by subtracting the yield of treated plot from yield of weed free plot and divided by yield of weed free plot multiply by 100. It is expressed in %.

$$WI = (YWF - YTP)/YWF \times 100 \quad \text{…. (1)}$$

Where,
YWF= Yield from weed free plot.
YTP= Yield from treated plot.

Green cob yield

The green cobs from each plot were harvested and recorded separately as q $plot^{-1}$ and converted into q ha^{-1}

Weed control efficiency (%)

Weed control efficiency was calculated at different growth stages *viz*., knee high, tasseling and maturity stages, using the weed dry matter per treatment on the basis of formula given by (Patel *et al*. 2006) [10] as:

$$WCE = (WC - WT)/WC \times 100 \quad \text{….. (2)}$$

Where,
WCE = Weed Control Efficiency

WC = Dry weight of weeds from control plot
WT = Dry weight of weeds from treated plot

Statistical Analysis

Population density and dry matter production of weed data was subjected to square root transformation √x + 0.5 in order to have normally distributed data. Mean separation was conducted for significant treatment means using least significance differences at 5% probability level**.**

Results and Discussion

The major weeds associated with the crop identified according to species during the crop growth both in conventional and zerotillage systems are given in table 1. The dominant grassy weed species found were *Cynodon dactylon*, *Sorghum helepense*, *Poa pratensis* and *Digitaria sanguinalis*; *Portulaca oleracea, Convolvulus arvensis, Amaranthus virdis, Chenopodium album, Xanthium strumarium, Anagalis arvensis, Polygonum aviculare, Veronica biloba, and Anthemis cotula* among broad leaf weeds, *and Cyprus rotundus* among sedges.

Table 3 shows that at 30DAS, 60 DAS and at harvest significantly lowest weed density was observed in case of conventional tillage over the zero tillage systems in both years of experimentation (24.97, 21.52 and 27.45, 28.01, No. m^{-2}), (53.43, 50.38 and 65.867, 59.48 No. m^{-2}), (80.26, 78.31 and 103.89, 97.44 No. m^{-2}), respectively. Conventional tillage practices reduces the weed density which enhances the good crop growth in maize and sunflower cropping system. (Murali Arthanari *et al.*, 2010) [6]. Among different weed management practices 100% weed density reduction was observed in case of weed free plot, in which hand weeding was given at 15, 30, 45, 60 DAS and was found at par with treatment T_5 in which Atrazine 1.0 kg ha^{-1} (PE) *fb*. Tembotrione 120 g ha^{-1} (PoE) at 25 DAS was given (10.40 and 9.18 No. m^{-2}), (24.40 and 20.29 No. m^{-2}), (60.09 and 55.28), respectively followed by rest of the treatments and significantly highest weed density was observed in case of weedy check (85.46 and 83.74 No. m^{-2}), (177.20 and 164.09 No. m^{-2}), (214.49 and 209.68 No. m^{-2}), respectively. These results are in conformity with Rana *et al.* (2017) [13] who observed that tembotrione 150 g ha^{-1} + surfactant and tembotrione 125 g ha^{-1}+surfactant applied on 20 DAS and tembotrione 150 g ha^{-1}applied on 30 DAS gave higher weed control efficiency, crop resistance index and efficiency index and lowest weed index over other treatments.

The weed dry matter Table 4 showed that Atrazine 1.0 kg ha^{-1} (PE) *fb*. Tembotrione 120 g ha^{-1} (PoE) at 25 DAS was able to control total weed density very effectively at all stages of crop growth i.e. 30 DAS, 60 DAS and at harvest. Better efficacy was obtained by the herbicides as against the control plot which showed the maximum weedy dry weight of the total weeds. The highest dry weight m^{-2} for all the weed species was observed in control and lowest was observed in weed free plot. Among the herbicidal treatments, the weed dry matter significantly decreased with the application of Atrazine 1.0 kg ha^{-1} (PE) *fb*. Tembotrione 120 g ha^{-1} (PoE) at 25 DAS compared to other treatments. Herbicides significantly reduce the weed intensity at all the stages of crop growth, hence dry matter production was low in treated plots. This resulted in highest green cob yield (Table 5) because of efficient control of weeds throughout the growth period and resulted in lowest weed index due to less competition for the nutrients, radiation and water from weeds facilitated the better growth and development of the crop. Improved grain yield with the application of herbicides in maize was also reported by (Takele, 2008) [16]. The results are in accordance with (owen *et al.*, 1993) [9] (Rasool *et al.*, 2020) [14] who reported that herbicides reduce weed infestation and control weeds well in maize crop in comparison to the control plot.

Conventional tillage resulted in significantly highest WCE at (fig 1) 60 DAS over Zero tillage because of more suppression of weeds in conventional tillage system in both years of experiment. Among weed management practices significantly highest WCE (fig. 1) (100%,100%) was observed at 60DAS in treatment T_7 i.e weed free plot and was found at par with treatment T_5 (86.27%, 87.36%) (Atrazine 1.0 kg ha^{-1} (PE) *fb*. Tembotrione 120 g ha^{-1} (PoE) at 25 DAS) followed by rest of the treatments. Significantly, lowest WCE (0%, 0%) was observed in weedy check in both years of experiment. These results are in conformity with Rana *et al.* (2017) [13]

Table 1: Initial soil characteristics

S. No.	Parameter	Value	Remark
1	Sand (%) Silt (%) Clay (%)	20.0 50.0 30.0	Soil texture: Silty clay loam
3	pH	6.76	Neutral
4	Electrical Conductivity (dS/m)	0.14	Normal
5	Organic Carbon (%)	0.74	Medium
6	Available N (kg/ha)	287	Medium
7	Available P (kg/ha)	12.75	Medium
8	Available K (kg/ha)	187	Medium

Table 2: The major weeds associated with the crop were identified according to species during the crop growth period of 2020-2021

	Scientific name	Family	Common name/Local name	Population (%)			
				CT 2020	ZT2020	CT2021	ZT2021
Grassy weeds	*Cynodon dactylon*	Poaceae	Bermuda grass (Dramoun)	7%	9%	6%	6%
	Sorghum halepense	Poaceae	Johnson's grass (Drahmi)	7%	10%	7%	12%
	Poa pratensis	Poaceae	Kentucky blue grass (Mahi ghass)	5%	6%	3%	3%
	Digitaria sanguinalis	Poaceae	Crab grass	7%	5%	4%	4%
Broad leaved	*Portulaca oleracea*	Portulacaceae	Common purslane (Nunner)	6%	8%	4%	4%
	Convolvulus arvensis	Convolvulacae	Field bind weed (Thir)	10%	11%	9%	9%
	Amaranthus viridis	Amaranthaceae	Pig weed (Lissi)	11%	10%	9%	9%
	Chenopodium album	Chenopodiacae	Common lambsquarters (Koni)	8%	7%	7%	6%

	Xanthium strumarium	Asteraceae	Cocklebur (Lansur)	6%	7%	3%	3%
	Anagallis arvensis	Primulaceae	Scarlet pimpernel (Chari saban)	6%	4%	3%	5%
	Polygonum aviculare	Polygonaceae	Prostrate knotweed (Durba ghas)	5%	5%	2%	4%
	Veronica biloba	Plantaginaceae	Two lobe speedwell	5%	5%	3%	6%
	Anthemis cotula	Asteraceae	Stinking chamom (Faki gassile)	7%	7%	2%	5%
Sedges	*Cyperus rotundus*	Cyperacae	Nut sedge (Zab, Mosti)	10%	11%	8%	9%

CT= Conventional Tillage
ZT= Zero Tillage

Table 3: Total weed density as influenced by tillage and herbicides in sweet corn (*Zea mays everta*)

	30DAS		**60DAS**		**At harvest**	
Tillage	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
CT	4.67 (24.96)	4.23 (21.52)	6.70 (53.43)	6.43 (50.38)	8.34 (80.26)	8.18 (78.31)
ZT	4.82 (27.45)	4.92 (28.01)	7.46 (65.86)	7.15 (59.48)	9.55 (103.89)	9.27 (97.43)
S.Em(±)	0.04	0.01	0.00	0.01	0.01	0.04
CD (P=0.05)	N/A	0.06	0.01	0.05	0.04	0.25
Weed Management						
T1	4.90 (23.00)	4.70 (21.28)	7.51(55.60)	7.23(51.49)	9.66 (92.89)	9.41(88.08)
T2	4.87 (22.80)	4.69 (21.08)	7.48 (55.20)	7.20 (51.09)	9.64 (92.49)	9.39 (87.68)
T3	4.86 (22.60)	4.66 (20.88)	7.46 (54.80)	7.17 (50.69)	9.62 (92.09)	9.37 (87.28)
T4	5.45 (28.80)	5.29 (27.08)	8.25 (67.20)	7.99 (63.09)	10.25 (104.49)	10.01(99.68)
T5	3.37 (10.40)	3.10 (9.18)	5.02 (24.40)	4.58 (20.29)	7.77 (60.09)	7.45(55.28)
T6	4.19 (16.60)	3.96 (14.88)	6.60 (42.80)	6.28 (38.69)	8.97 (80.09)	8.70 (75.28)
T7	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00(0.00)	1.00 (0.00)	1.00 (0.00)
T8	9.29 (85.46)	9.20 (83.74)	13.33 (177.20)	12.85 (164.09)	14.66 (214.49)	14.51 (209.68)
S.Em(±)	0.08	0.06	0.10	0.07	0.12	0.08
CD (P=0.05)	0.24	0.16	0.30	0.20	0.35	0.23

Table 4: Total weed dry matter accumulation (g m^{-1}) as influenced by tillage and herbicides sweet corn (*Zea mays everta*)

	30DAS		**60DAS**		**AT HARVEST**	
Tillage	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
CT	3.36 (10.29)	2.89 (9.09)	4.72 (25.79)	4.15 (21.19)	6.93 (57.04)	7.06 (58.73)
ZT	3.62 (11.59)	3.34 (11.80)	5.33 (32.35)	4.95 (27.87)	8.16 (76.07)	7.66 (67.60)
S.Em(±)	0.023	0.014	0.012	0.007	0.013	0.034
CD (P=0.05)	0.152	0.093	0.076	0.049	0.085	0.223
Weed Management						
T1	3.69 (9.89)	3.20 (9.31)	5.29 (27.16)	4.79 (22.24)	8.08 (64.79)	7.86 (60.93)
T2	3.66 (9.81)	3.19 (9.23)	5.27 (26.97)	4.77 (22.05)	8.05 (64.43)	7.83 (60.56)
T3	3.65 (9.73)	3.18 (9.15)	5.26 (26.78)	4.76 (21.87)	8.03 (64.07)	7.81(60.19)
T4	4.18 (12.15)	3.54 (11.56)	5.79 (32.63)	5.34 (27.72)	8.71 (75.35)	8.50 (71.48)
T5	1.86 (4.49)	2.18 (4.01)	3.61 (12.20)	2.78 (7.29)	5.91 (34.96)	5.64 (31.08)
T6	3.06 (7.40)	2.78 (6.82)	4.69 (21.11)	4.11(16.19)	7.31 (53.15)	7.08 (49.28)
T7	1 (0.00)	1 (0.00)	1 (0.00)	1 (0.00)	1 (0.00)	1 (0.00)
T8	6.84 (34.09)	5.87 (33.51)	9.31 (85.75)	8.85 (77.39)	13.29 (175.66)	13.14(171.79)
S.Em(±)	0.072	0.073	0.094	0.043	0.075	0.079
CD (P=0.05)	0.211	0.213	0.273	0.125	0.219	0.229

Table 5: Weed index (%) and green cob yield (q ha^{-1}) as influenced by tillage and herbicides in sweet corn (*Zea mays everta*)

Tillage	**WI (%)**		**Green cob yield(q ha^{-1})**	
	2020	**2021**	**2020**	**2021**
CT	18.52	17.42	187.97	202.97
ZT	18.16	17.93	161.46	176.25
S.Em(±)	0.351	0.065	2.02	2.09
CD (P=0.05)	NS	0.394	12.31	12.72
T1	18.80	18.86	170.63	185.63
T2	22.26	22.11	165.74	180.74
T3	14.65	14.89	182.06	197.06
T4	36.249	31.487	140.98	155.98
T5	2.50	2.23	206.28	221.28
T6	5.461	5.377	203.16	218.16
T7	0.000	0.000	207.27	222.27
T8	46.78	46.47	121.61	135.78
S.Em(±)	0.80	1.58	4.35	4.33
CD (P=0.05)	2.33	4.589	12.61	12.53

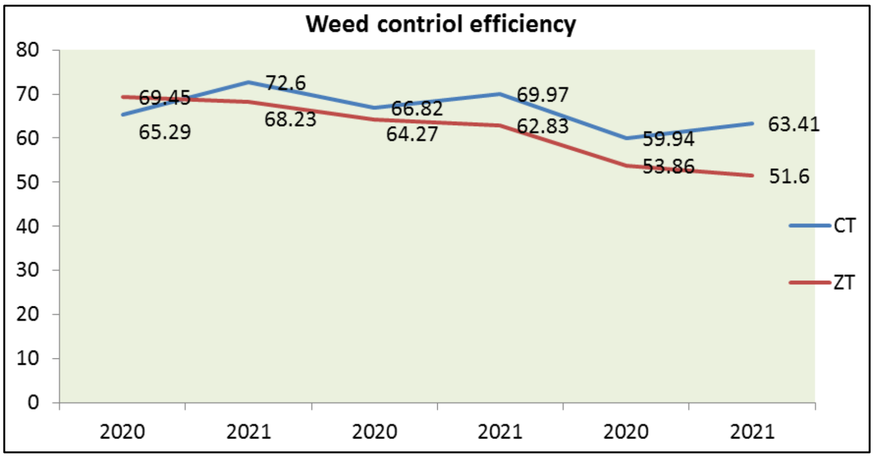

Fig 1: Weed control efficiency as influenced by conventional and zero tillage

Conclusion

It is concluded from the two years experiment that the treatment conventional tillage was found effective in reducing weed biomass of all weeds and improving green cob yield of sweet corn as compared to zero tillage and among herbicide treatments treatment T_5 (Atrazine 1.0 kg ha^{-1}(PE) *fb*. Tembotrione 120 g ha^{-1} (PoE) at 25 DAS) considerably showed efficient control of weeds and hence resulted in enhanced green cob yield over rest of the treatments.

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