The Journal of Agricultural Science

cambridge.org/ags

Crops and Soils Research Paper

Cite this article: Niknam N, Farajee H, Dehnavi MM, Yadavi A (2022). Yields and weed management of sweet corn as influenced by seedbed preparation methods and wheat residues rates. *The Journal of Agricultural Science* **160**, 302–309. https://doi.org/10.1017/S0021859622000296

Received: 15 December 2021
Revised: 9 April 2022
Accepted: 14 May 2022
First published online: 20 July 2022

Key words:
Carbohydrate; emergence; fresh ear; proline; water productivity

Author for correspondence:
Hooshang Farajee,
E-mail: Hooshangfarajee@yahoo.com

Yields and weed management of sweet corn as influenced by seedbed preparation methods and wheat residues rates

Nasrin Niknam, Hooshang Farajee, Mohsen Movahhedi Dehnavi and Alireza Yadavi

Department of Agronomy and Plant Breeding, Faculty of Agriculture, Yasouj University, Yasuj, Iran 7591874934

Abstract

One of the challenges to improve sweet corn [*Zea mays* var. Saccharata (Sturtev.) L. H. Bailey] production is finding a way to increase crop establishment and decrease weed infestation. Crop establishment and weed control are of prime importance in sweet corn production. Three methods of seedbed preparation including pre-planting irrigation before ridge-furrow preparation, pre-planting irrigation after ridge-furrow preparation and irrigation after planting, and four wheat (*Triticum aestivum* L.) residue rates (0, 250, 500 and 750 g/m^2) were arranged in a split plot based on a randomized complete blocks design. Higher seedling emergence and weed control were significantly obtained in pre-planting irrigation than irrigation after planting treatments. Wheat residue mulching reduced soil moisture depletion, proline and soluble carbohydrates contents with decreasing weed biomass. The efficiency of weed management was found to be ensured using pre-planting irrigation coupled with wheat residues application. The grain yield was the highest (1433 g/m^2) using pre-planting irrigation and wheat residue mulching (750 g/m^2). Weed biomass decreased by 58% in pre-planting irrigation after ridge-furrow preparation and wheat residue mulching (750 g/m^2) compared to irrigation after planting and no-mulching treatment. Therefore, pre-planting irrigation after ridge-furrow preparation and wheat residues application (500–750 g/m^2) were optimal management practices for crop establishment and weed control to improve yields and water productivity of sweet corn in the region.

Introduction

Crop yield and resource use efficiency depend on successful plant establishment in the field. Furthermore, a compacted topsoil layer decreases plant density (Reis *et al*., 2011). Consequently, sweet corn growers may primarily fail to have satisfactory crop performance. To resolve this problem, the initial irrigation is usually performed immediately after sowing, followed by several additional irrigations with 2–3 day intervals. Increased water consumption is the disadvantage of the initial frequent irrigation. In other view, initial frequent irrigation increases weed growth.

Weeds compete for water, decrease water availability and contribute to crop water stress (Zimdahl, 2018). Thus, sustainable strategies for weed management are essential during the early stages of crop growth. Researchers suggest the wet planting method for resolving this problem through decreasing soil compaction in the seedbed. This method is common in several regions worldwide, even in plants with high water requirements for germination, such as beans (*Phaseolus vulgaris* L.) (Ghanbari *et al*., 2020). The pre-planting irrigation method effectively decreases the weed density (Hemmati *et al*., 2011). Furthermore, when irrigation volume is limited, pre-planting irrigation may be most cost-effective (Kisekka *et al*., 2017).

Mulching plays an important role in reducing weed population. As stated by Olabode and Sangodele (2015), the highest weed population (21.9 plants/m^2) was recorded in unmulched plots, whereas the lowest weed population was in white plastic mulch. Among various mulches, wheat residue mulching is a good option because of its low cost, availability and environmental compatibility. The appropriate wheat residue mulching rate is an essential factor that influences the effectiveness of mulching for weed control. It is reported that weed suppression in corn and soybean (*Glycine max* L.) was positively correlated with the biomass of plant residues (Pittman *et al*., 2020). Uwah and Iwo (2011) reported the highest weed infestation in corn (*Zea mays* L.) in unmulched plots, whereas the lowest weed infestation was found with 8 t/ha mulch. In another study, the minimum weed dry biomass in rice (*Oryza sativa* L.) was achieved with 10 t/ha surface residues (Ranaivoson *et al*., 2018). Similarly, sorghum (*Sorghum bicolor* L.) mulch (6 t/ha) in wheat fields decreased weeds density by 58% as compared with the unmulched treatments (Loura *et al*., 2020).

Soil mulching affects weeds and decreases soil moisture depletion compared with bare soil. Lower water loss leads to more available water to plants (Stelli *et al*., 2018). Water conservation and yield in spring corn were the highest with application of 9000 kg/ha residue mulch (Cai *et al.*, 2015). Increased soil water content was also found to increase water productivity. Researchers suggest mulching can decrease the harmful effects of water deficiency by improving weed control (Shen *et al.*, 2012; Rannu *et al.*, 2018); nevertheless, mulch type and thickness exert varying effects on weed control, yield and water productivity.

The literature review shows that application of mulches has been addressed in some crop production. However, no study has been conducted in which advantages of both planting methods and mulching on weed management and sweet corn production have been reviewed. Our results can help to guide growers better. Thus, the objectives of our study were (i) to introduce an appropriate seedbed preparation method for better seedling establishment and (ii) to determine the best mulch treatment and seedbed preparation method for better control of weeds to ultimately increase grain yield and water productivity of sweet corn.

Materials and methods

Field site description

This experiment was conducted in 2017 and 2018 in Mamassani, Fars Province, a subtropical region in southwestern part of Iran (51°32′N, 31°13′E and 900 m above sea level). The seasonal pattern of climatic conditions during the growing season is shown in Table 1. The soil samples were taken from a depth of 0–30 cm before planting and analysed for physical and chemical properties and are shown in Table 2.

Field experiment design, crop management, and measurements

The experiment was conducted as a split plot arranged on a randomized complete blocks design with four replications. Seedbed preparation methods were assigned in mainplots and the wheat residue mulching rates were applied in subplots. The three methods of seedbed preparation included pre-planting irrigation before ridge-furrow preparation (P1), pre-planting irrigation after ridge-furrow preparation (P2) and irrigation after planting (P3). Wheat residue was placed at 0 (M1 as control), 250 (M2), 500 (M3) and 750 g/m^2 (M4). It should be noted that crop residues were obtained from wheat straw. Sweet corn was planted after wheat, but there was no straw in the field at the time. In fact, straw was collected after the wheat harvest in spring. After seedbed preparing, collected residues from the previous crop were spread all over the seedbed surface.

Seeds were planted on the ridges after tillage and soil preparation in furrows and ridges. The ridges were 15–20 cm high, row spacing was 75 cm, in-row plant spacing was 26 cm and plant density was 51 000/ha. The plowing depth was also 25 cm. Planting was immediately followed by mulching. Sweet corn seeds (Obsession hybrid, a super-type hybrid, Seminis Company, USA) were manually sown at a 4–5 cm depth of ridges. Two seeds were sown in each hole to ensure the uniformity of plant density. Seedlings were thinned at the three-leaf stage to achieve 51 000/ha.

In the after-planting irrigation method (P3), irrigation was performed three times during seed establishment according to normal irrigation in the region. The first irrigation occurred in dry soil just after sowing. To help the sprouted seeds break the soil, light irrigations were performed again by the drip system 3 days after sowing, which was repeated 3 days later. In the pre-planting irrigation methods (P1 and P2), the soil was irrigated 4 days before planting. Then, pre-planting treatments were not irrigated until seedling establishment was completed. Initial irrigation was performed after ridge-furrow preparation for P2 treatment, whereas it was irrigated before ridge-furrow preparation for P1 treatment. The preparation stages of planting treatment are shown in Fig. 1.

After the seedling establishment (12 days after planting), irrigation was similar for all the treatments during the growing season. No effective precipitation occurred during the growing season of sweet corn, and the volume of irrigation water used in both years was similar. The volume of irrigation water in the P3 treatment was 900 m^3/ha, whereas 400 m^3/ha was applied in the P1 and P2 treatments separately during germination and crop establishment stages. The total amounts of consumed water for the P1, P2 and P3 treatments were 9400, 9400 and 9900 m^3/ha, respectively.

Table 1. Average monthly weather data during experimental years

Month	Maximum temperature (°C)		Minimum temperature (°C)		Total rainfall per month (mm)	
	2017	2018	2017	2018	2017	2018
August	42	43.2	25.2	24.9	0	20.8
September	38.5	41	21.1	22.2	0.2	3.5
October	33.9	34.3	15	17.2	2.4	0
November	27.7	22.3	9.8	12.3	138.2	23.8
December	18.7	18.7	4.9	5.9	114.4	42.5

Table 2. Soil physical and chemical properties

Year	Depth	Sand	Silt	Clay	EC	pH	OC	N	P	K
	(cm)		(%)		(dS/m)	–	(%)	(%)	(mg/kg)	
2017	0–30	32	38	30	2.3	7.5	0.76	0.08	8.61	160
2018	0–30	35	35	33	2.0	7.6	0.72	0.09	8.01	168

EC, electrical conductivity; OC, organic carbon; N, nitrogen; P, phosphorus; K, potassium

https://doi.org/10.1017/S0021859622000296 Published online by Cambridge University Press

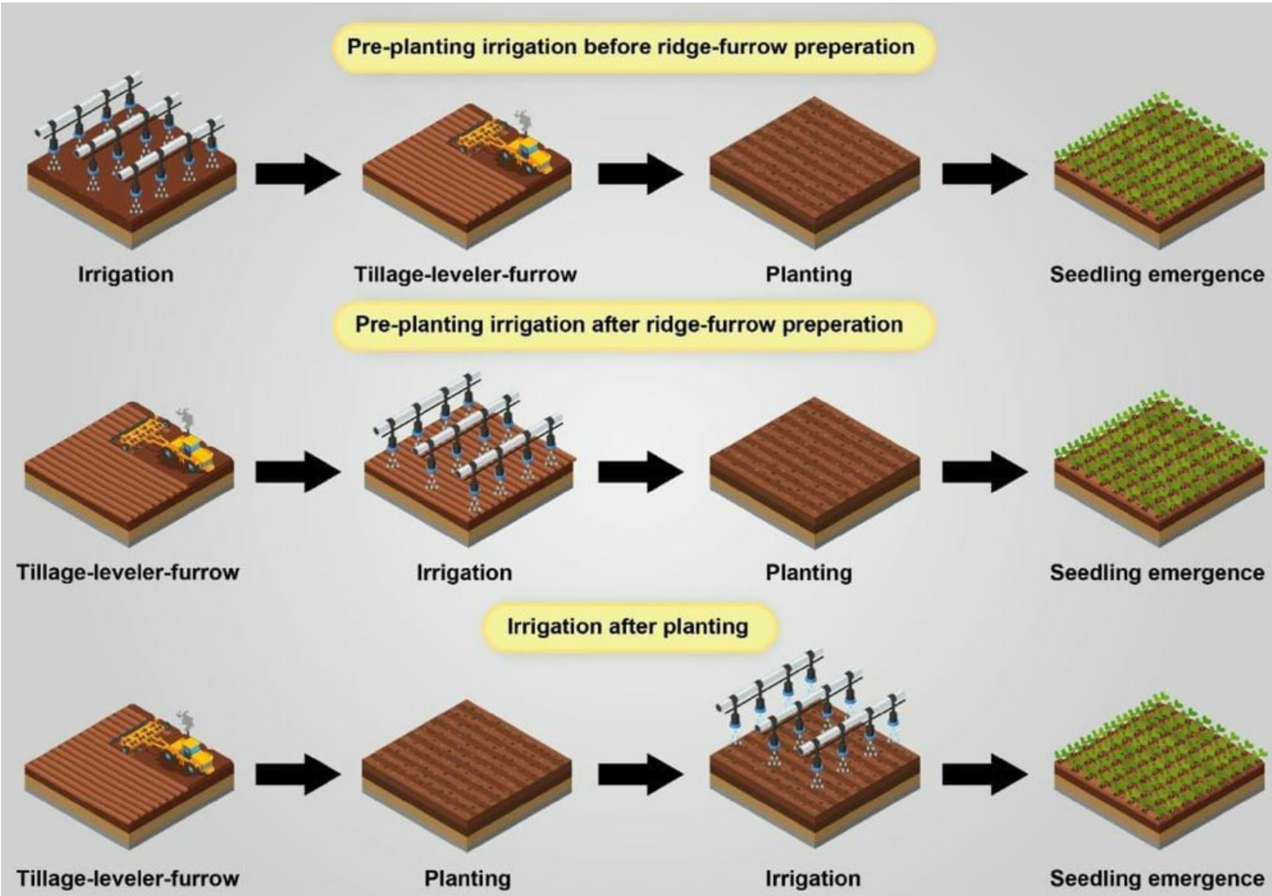

Fig. 1. Colour online. Stages of seedbed preparation.

To measure soil moisture depletion during the growing season, soil samples were taken from the depth of root development in the experimental plots 24 h before irrigation. The samples were weighed and dried in an oven at 105°C for 24 h. The soil water content for different methods of seedbed preparation and mulching rates are shown in Figs 2(*a*) and (*b*).

N, P and K were applied in the forms of urea (230 kg/ha urea), triple superphosphate (40 kg/ha) and potassium sulphate (115 kg/ha), respectively. Phosphorus and potassium fertilizers were applied at the sowing time. Urea fertilizer was applied in three equal splits: at sowing (76 kg/ha), at the six-to-seven-leaf stage (76 kg/ha) and finally at the tasseling stage (76 kg/ha).

The emerged seedlings were counted every day until 12 days after planting. Seedling emergence was defined as the time when the crop was visible on the soil surface. The seedling emergence rate, mean emergence time and seedling emergence percentage were calculated as follows:

$$R = \sum^{n} / \sum^{dn (\text{Ram et al., 1989})} \tag{1}$$

$$\text{MET} = \sum^{dn} / \sum^{n}$$

where R is seedling emergence rate, MET is mean seedling emergence time, n is the number of emerged seeds during d days and d is the number of days. Emergence percentage was obtained by dividing number of emerged seedlings by total number of seeds sown, multiplied by 100 (Soltani *et al.*, 2006).

Weed biomass and density were evaluated at the harvest stage. Weeds were not controlled throughout the growing season in any of the experimental plots. They were manually removed from the area of 2 m^2 and brought to the laboratory. Then, dry weed biomass was determined after oven drying at 70 °C for 72 h. In this experiment, the most dominant weed species were *Sorghum halepense* L. (Johnsongrass) and *Chenopodium album* L. (common lambsquarters). Other weed species were *Portulaca oleracea* L. (purslane), *Cyperus rotundus* L. (Cyperaceae) and *Echinochloa crus-galli* P. Beauv. var. *oryzicola Ohwi* (barnyard grass). Johnsongrass was present because of seed germination.

At the tasseling stage, before starting irrigation, fully expanded young fresh leaves were removed at 2 p.m. The samples were used to measure leaf proline content and soluble carbohydrates. Leaf proline content was determined following Bates *et al.* (1973). Leaf samples (0.5 g) were homogenized in a 10 ml of sulfosalicylic acid (3%) solution, and leaf proline content was measured at 625 nm using a spectrophotometer (Perkinelmer Company, USA) and expressed as μmol/mg fresh leaf. Soluble carbohydrates were extracted using the method developed by Irigoyen *et al.* (1992), and carbohydrates content in this extract was read at 625 nm using a spectrophotometer (model Vis 2100) and expressed as mg/g fresh leaf.

In the ripening stage, the four inner rows were harvested and marketable ear yield and canned yield for each plot were recorded.

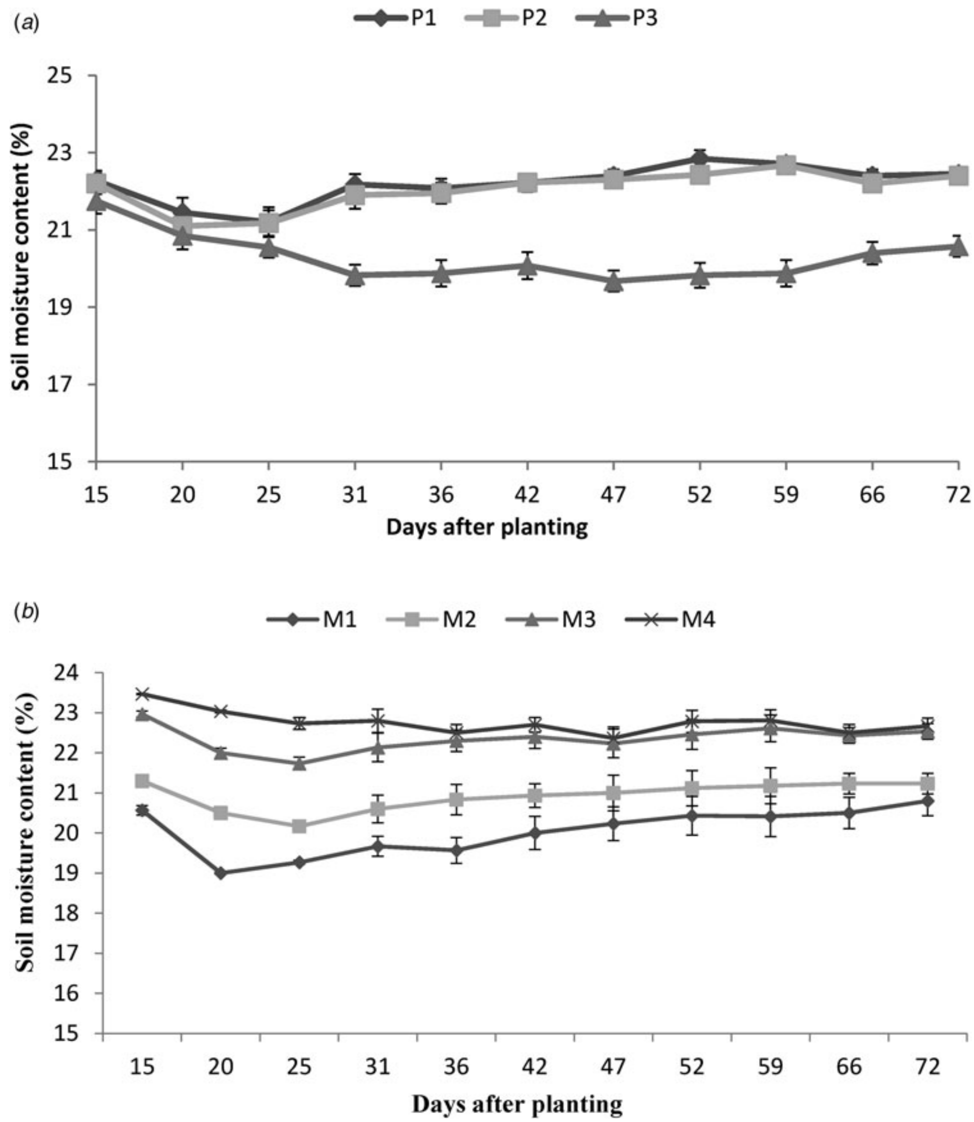

Fig. 2. Soil moisture content before each irrigation for methods of seedbed preparation (*a*) and wheat residues rates (*b*). P1, pre-planting irrigation before furrow-ridge preparation; P2, pre-planting irrigation after furrow-ridge preparation; P3, irrigation after planting; M1, no wheat residues; M2, 250 g/m^2 wheat residues; M3, 500 g/m^2 wheat residues; M4, 750 g/m^2 wheat residues.

Water productivity was computed as the ratio of canned grain yield to the supplied water as follows (Zhou *et al*., 2011):

$$\mathrm{WP} = Y/\mathrm{Wi} \quad (2)$$

where WP is water productivity, Y is canned yield (kg) and Wi is supplied water (m^3).

An analysis of variance (ANOVA) was run for all data using SAS version 9.1 software (SAS Institute, Cary, NC, USA). The Bartlett test and the data normality test were conducted before statistical analysis. The means were compared using the LSD test in all significant interactions.

Results

The ANOVA showed a significant effect of the seedbed preparation methods on seedling emergence rate, time and seedling emergence percentage traits (Table 3). Seedling emergence percentage and rates were significantly higher when the plots were irrigated at pre-planting after ridge-furrow preparation than other treatments (Table 4).

However, crop emergence time was significantly higher when it was irrigated after planting than pre-planting after and before ridge-furrow preparation (Table 4). Crop residues application did not affect seedling establishment traits.

Seedbed preparation methods and wheat residue mulching rates had a significant effect on weed biomass and density (Table 3). Pre-planting irrigation after ridge-furrow preparation with 750 g/m^2 wheat residue treatment decreased weed biomass and weed density more effectively than other treatments (Table 5).

The results showed that seedbed preparation methods and wheat residue mulching rates had a significant effect on proline and soluble carbohydrate contents (Table 3). Among seedbed preparation methods, irrigation after planting had the highest effects on proline and soluble carbohydrate contents compared with the pre-planting irrigation treatments (Table 6). Increasing

https://doi.org/10.1017/S0021859622000296 Published online by Cambridge University Press

Table 3. Analysis of variance of the effect of seedbed preparation methods and wheat residues rates on the sweet corn traits for 2 years

SOV*	df	RSE	TSE	SEP	WB	WD	Pro	SC	FEY	CY	WP
Y	1	0.67^{ns}	1.97^{ns}	455^{ns}	2428**	346.7**	0.27^{ns}	0.53^{ns}	572 360**	212 929**	0.29**
R (Y)	6	0.31	1.17	75	199	20.0	0.32	58.10	4666	21 363	0.03
P	2	17.10**	38.54**	3319**	7605**	951.1**	2.84**	190.55**	1 653 317**	184 432**	1.23**
Y × P	2	1.33^{ns}	0.27^{ns}	394^{ns}	221^{ns}	217.0**	0.14^{ns}	19.08^{ns}	1569^{ns}	12 409^{ns}	0.02^{ns}
Error a	12	0.89	3.02	185	65	40.4	0.19	33.91	13 345	22 283	0.04
M	3	0.85^{ns}	1.24^{ns}	312^{ns}	11 292**	2327.9**	1.51**	1135.71**	1 570 224**	820 821**	0.91**
Y × M	3	0.03^{ns}	0.01^{ns}	10^{ns}	705**	0.3**	0.07^{ns}	37.10^{ns}	9343^{ns}	19 619^{ns}	0.01^{ns}
P × M	6	0.14^{ns}	0.11^{ns}	38^{ns}	241*	86.2*	0.01^{ns}	56.01^{ns}	26733 *	30 647**	0.05*
Y × P × M	6	0.17^{ns}	0.04^{ns}	41^{ns}	114^{ns}	4.2^{ns}	0.02^{ns}	24.26^{ns}	9521^{ns}	33 265^{ns}	0.01^{ns}
Error b	54	0.41	1.02	149	101	20.3	0.16	24.25	11 292	12 974	0.02
CV (%)		23.80	20.81	15	11	16.7	16.30	11.11	10	11	12.16

ns, * and **, non-significant and significant at 5 and 1% probability levels, respectively; SOV*, sources of variations; df, degree of freedom; RSE, rate of seedling emergence; TSE, time of seedling emergence; SEP, seedling emergence percentage; WB, weed biomass; WD, weed density; Pro, proline; SC, soluble carbohydrates; FEY, fresh ear yield; CY, canned yield; WP, water productivity; Y, year; R, replication; P, seedbed preparation methods; M, wheat residues mulching rates.

Table 4. Seedling emergence rate, time and percentage as affected by methods of seedbed preparation for 2 years

Planting method	Seedling emergence rate (plant/day/m^2)	Mean emergence time (day)	Seedling emergence percentage (%)
P1	1.91b	4.45b	80b
P2	2.38a	4.04b	92a
P3	1.19c	6.41a	68c

The means with similar letters in each section, according to LSD test, are not significantly different at P<0.05. P1, pre-planting irrigation before furrow-ridge preparation; P2, pre-planting irrigation after furrow-ridge preparation; P3, irrigation after planting

wheat residue rates decreased the trend of proline and soluble carbohydrate contents. The highest and the lowest carbohydrate contents were obtained from 0 and 750 g/m^2 wheat residue, respectively (Table 6).

Fresh ear and canned grain yield, which are the marketable yields of sweet corn, were significantly affected by the combinations of seedbed preparation methods and wheat residue rates (Table 3). The highest fresh ear and canned grain yield were obtained when crop was irrigated and planted after ridge-furrow preparation and 750 g/m^2 of wheat residues was applied (Table 5).

There was a significant interaction between seedbed preparation methods and wheat residues application for water productivity (Table 3). The highest water productivity was obtained when wheat residues (particularly 750 g/m^2) were applied and land was prepared with pre planting irrigation after ridge-furrow (Table 5).

Discussion

The lowest seedling emergence rate occurred when sweet corn was irrigated after planting. Seedbed moisture content of this treatment was further compared with the pre-planting irrigation treatments during the germination period. These findings demonstrated that seedbed moisture was not a limiting factor for a good crop establishment, whereas other properties of seedbed affected crop establishment. Soil resistance and compaction increased with increasing successive irrigations (Hamza and Anderson, 2003). When the crop was irrigated after planting, initial frequent irrigations may have contributed to soil compaction near the seed. Topsoil compaction decreases oxygen availability for seed germination (Li *et al.*, 2010; Weisskopf *et al.*, 2010). Hence, soil compaction promotes late and a lower germination rate (Nawaz *et al.*, 2013). Finch-Savage and Bassel (2016) also claimed that seedling emergence was negatively affected by seedbed compaction. However, reduced initial irrigations decreased soil compaction during the germination stage when the crop was irrigated after pre-planting. Pre-planting irrigation enhanced crop establishment as expected compared with when the crop was irrigated after planting. Pre-planting irrigation after ridge-furrow preparation was the most fitting planting method for crop establishment, because seeds were compressed and covered with soil to form a suitable seedbed.

Weed biomass and density of the pre-planting irrigation after ridge-furrow preparation with 750 g/m^2 wheat residue was significantly lower than the other treatments. Increasing crop residue rate lowered weed biomass and density. Research suggests light can significantly promote germination in many weed species (Ahmed *et al.*, 2015). Light restrictive practices such as mulching can help most effectively manage weeds (Ahmed *et al.*, 2015). In contrast, cover crop residue can significantly contribute to repressing smaller-seeded weeds (e.g., common lambsquarters) given their inadequate carbohydrate reserve for growing under mulched conditions (Pittman *et al.*, 2020). The present study mainly investigated photoblastic weeds such as Johnsongrass and common lambsquarters. Residue mulching prevented weed germination by obstructing the light reaching the weed seeds. Decreasing the weed density lowered the weed biomass. There was a significant positive correlation between the weed density and the weed biomass ($r = 0.74$**) (Table 4). Wheat residue mulching therefore

https://doi.org/10.1017/S0021859622000296 Published online by Cambridge University Press

Table 5. Weed density, biomass, ear yield, canned grain yield and water productivity as affected by methods of seedbed preparation for 2 years

Planting method	Crop residues rates	Weed density (plant/m^2)	Weed biomass (g/m^2)	Ear yield (g/m^2)	Canned grain yield (g/m^2)	Water productivity (kg/m^3)
P1	M1	39.6b	134.0b	1793h	969de	1.07de
	M2	30.3cd	109.4de	1955g	1036cd	1.15cd
	M3	19.6fg	80.7f	2405cd	1224b	1.36b
	M4	17.0gh	72.0fg	2482bc	1317a	1.44ab
P2	M1	33.3c	121.5c	2133f	911ef	0.99de
	M2	23.1ef	101.7e	2352de	1153bc	1.28c
	M3	14.1h	71.1g	2573ab	1337a	1.60a
	M4	12.6h	61.3h	2672a	1433a	1.59a
P3	M1	48.3a	146.6a	1532i	793f	0.72f
	M2	43.1b	132.6b	1794h	875ef	0.79f
	M3	26.6de	116.2cd	2041fg	1091cd	0.95ef
	M4	15.6gh	102.1e	2263e	1377a	1.25c

The means with similar letters in each section, according to LSD test, are not significantly different at P<0.05. P1, pre-planting irrigation before furrow-ridge preparation; P2, pre-planting irrigation after furrow-ridge preparation; P3, irrigation after planting; M1, no wheat residue; M2, 250 g/m^2 wheat residue; M3, 500 g/m^2 wheat residue; M4, 750 g/m^2 wheat residue.

Table 6. Effect of methods of seedbed preparation and mulching rates on proline and soluble carbohydrate contents of sweet corn leaf for 2 years

Experimental factors	Proline (μmol/g)	Soluble carbohydrate (mg/g)
Planting method		
P1	7.48b	42.85b
P2	5.75c	42.03b
P3	8.25a	47.27a
Crop residues rates		
M1	8.53a	53.71a
M2	8.36a	47.23b
M3	6.01b	38.94c
M4	5.37b	36.32c

The means with similar letters in each section, according to LSD test, are not significantly different at P<0.05. P1, pre-planting irrigation before furrow-ridge preparation; P2, pre-planting irrigation after furrow-ridge preparation; P3, irrigation after planting; M1, no wheat residue; M2, 250 g/m^2 wheat residue; M3, 500 g/m^2 wheat residue; M4, 750 g/m^2 wheat residue.

effectively reduced weed biomass by decreasing weed density. Wayayoka *et al.* (2014) reported the highest weed biomass (16.17 g/m^2) with no mulch treatments and mulch at the lowest weed biomass (0.26 g/m^2). Similarly, Ngwira *et al.* (2014) found rice residue (2.5 t/ha) decreased weed density.

Pre-planting irrigation after ridge-furrow preparation decreased weed density and biomass and better crop establishment. A significant negative correlation was found between crop seedling emergence rate and weed biomass ($r = -0.52^{**}$) (Table 7). Rapid soil surface drying in these treatments led to a more significant reduction in weed emergence compared with irrigation after planting method. It has also been reported that even early light irrigation can increase emerging weeds, and the wetted surface increase by increasing the volume of applied water (Bajpai and Kaushal, 2020). Hence, frequent primary irrigations when the crop was irrigated after planting increased emerged weeds compared with pre-planting irrigation treatments because of horizontal elongation of the wetting pattern in the planting row. Thus, changing the planting method by improving seedling establishment was an influential factor in decreasing weeds. However, the planting method must be combined with wheat residue mulching to achieve an acceptable weed control.

Proline and leaf soluble carbohydrate contents were higher when the crop was irrigated after planting than pre-planting irrigation. Non-toxic compounds, including proline and carbohydrates, accumulated in plants can protect cells from damage by lowering the water content of cells (Krasensky and Jonak, 2012; Lipiec *et al.*, 2013). Increased weed biomass followed by increased soil moisture depletion affected proline and soluble carbohydrate contents in irrigation after planting treatment. Correlations between weed biomass with proline ($r = 0.58^{**}$) and soluble carbohydrates were significant and positive ($r = 0.76^{**}$) (Table 4). Sinay and Karuwal (2014) reported the highest contents of proline and soluble carbohydrates in chickpea (*Cicer arietinum* L.) in water-deficit treatment with a 12-day irrigation interval.

Mulching reduced the soil moisture depletion and the proline and soluble carbohydrate contents by decreasing weed biomass. Kumar and Lal (2012) also argued that aluminium reflective mulch prevents the growth of weeds in squash (*Cucurbita pepo* L.) and thus helps retain soil moisture. Furthermore, different types of mulch such as rice residue, husk and grasses decreased the water loss caused by weeds (Abouziena *et al.*, 2014).

The highest fresh ear and canned grain yield were obtained when the crop was irrigated after ridge-furrow preparation and application with 750 g/m^2 of wheat residues which can be explained by the positive effects of mulching on weed management. As discussed earlier, the proline and soluble carbohydrate contents increased with increased soil moisture depletion by the weeds. There were significant negative correlations between weeds biomass and canned grain yield ($r = -0.51^{**}$). Pittman *et al.* (2020) reported that weed-free treatments increased corn yield compared to weedy ones. Similarly, Armengot *et al.* (2013) found weed treatment decreased wheat yield by 11.4% compared to weed-free treatments. Silk emergence is sensitive to weed interference in a way that weeds

Table 7. Pearson's correlation coefficients between traits of sweet corn for 2 years

	1	2	3	4	5	6	7	8	9	10
1. RSE	1									
2. TSE	−0.35**	1								
3. PSE	0.82**	−0.34**	1							
4. WB	−0.52**	0.26^{ns}	−0.52**	1						
5. WD	−0.42**	0.18^{ns}	−0.41**	0.74**	1					
6. FEY	0.32**	−0.11^{ns}	0.36**	−0.55**	−0.73**	1				
7. CY	0.35**	−0.11^{ns}	0.36**	−0.51**	0.19^{ns}	0.66**	1			
8. WP	0.54**	−0.32**	0.51**	−0. 62**	0.22*	0.94**	0.83**	1		
9. Pro	−0.48**	0.37**	−0.48**	−0.58**	0.53**	−0.64**	−0.52**	−0.61**	1	
10. SC	−0.31**	0.16^{ns}	−0.31**	0.76**	0.66**	−0.67**	−0.65**	−0.63**	0.48**	1

ns, * and **, respectively, non-significant and significant at 5 and 1% probability level of error.
RSE, rate of seedling emergence; TSE, time of seedling emergence; PSE, per cent of seedling emergence; WB, weeds biomass; WD, weed density; FEY, fresh ear yield; CY, canned yield; WP, water productivity; Pro, proline; SC, soluble carbohydrate.

postponed primary growth and development in corn, which negatively affects grain performance (Williams *et al*., 2014). Sweet corn yield increased with weed suppression method (Table 5), and crop residues application. Mulching also increased soil moisture (Fig. 1 (*b*)) by lowering the weed biomass. Crop residues therefore decreased weeds, and improved soil moisture (Table 7), which increased fresh ear and canned yield.

Since there was no significant difference between 750 and 500 g/m^2 wheat residue on fresh ear and canned yield when the crop was irrigated before planting after ridge-furrow preparation, the pre-planting irrigation after ridge-furrow preparation with 500 g/m^2 wheat residue rate appears to be more economical and environmentally sustainable. Reportedly, rapid crop establishment supplies a competitive benefit to crop (Scavo and Mauromicale, 2020). Improved seedling establishment in the pre-planting irrigation after ridge-furrow preparation treatment led to a better control of weeds; these treatments did not require crop residues application.

Application of wheat residues (especially 750 g/m^2) and the pre-planting irrigation after ridge-furrow preparation improved water productivity. Water productivity increased with increasing wheat residues rates (particularly 750 g/m^2), because of its effect on reducing weeds. Weeds consume the same amount of water as crop plants use and further weed growth leads to higher water consumption and more water loss (Zimdahl, 2018). Weed density was directly related to the depletion of soil moisture and had a significant adverse effect on water productivity (Dalley *et al*., 2006). When 750 g/m^2 of wheat residue was applied, weed biomass decreased accompanied by decrease in slope of moisture depletion in 0–30 cm of soil depth (Fig. 1(*b*)) where most sweet corn roots are concentrated. Hence, crop residues reduce weed infestation, which lead to improved water productivity. Kumar and Lal (2012) claimed that applying white or aluminium reflective mulch helped preventing weed growth and soil water loss in squash during dry years. Similarly, Wang *et al.* (2012) showed that residue mulching increased grain yield of corn, which leads to higher water productivity.

Pre-planting irrigation improved germination and plant stand establishment and weed growth was low and consequently soil moisture depletion was lower compared to irrigation after planting (Fig. 1(*a*)). Indeed, water productivity was higher when the crop was irrigated and planted after ridge-furrow preparation and application with 750 g/m^2 of wheat residues.

Conclusion

Pre-planting irrigation of sweet corn with wheat residue (500–700 g/m^2) improved grain yield and water productivity. There was a significant increase in the crop yield caused by crop residues application and appropriate seedbed preparation methods which improved seedling establishment and weed control. Given the positive effects of these factors on seedling establishment, weed control, water productivity and grain yield, they appear to be more economical and environmentally sustainable.

Author Contributions. N. Niknam contributed to conceptualization, investigation, resources, writing – original draft. H. Farajee contributed to validation, investigation, resources, writing – review and editing, supervision, project administration. M. Movahhedi Dehnavi contributed to validation, investigation, resources, writing – review and editing, supervision, project administration. A. Yadavi contributed to validation, investigation, writing – review and editing, supervision, project administration.

Financial support. This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of interest. None.

Ethical standards. Not applicable.

References

Abouziena HF, El-Saeid HM and Amin A (2014) Water loss by weeds: *a review. International Journal Chemtech Research* 7, 323–336.
Ahmed S, Opeña JL and Chauhan BS (2015) Seed germination ecology of doveweed (*Murdannia nudiflora*) and its implication for management in dry-seeded rice. *Weed Science* **63**, 491–501.
Armengot L, José-María L, Chamorro L and Sans FX (2013) Weed harrowing in organically grown cereal crops avoids yield losses without reducing weed diversity. *Agronomy for Sustainable Development* **33**, 405–411.
Bajpai A and Kaushal A (2020) Soil moisture distribution under trickle irrigation: a review. *Water Supply* **20**, 761–772.
Bates LS, Waldren RP and Teare I (1973) Rapid determination of free proline for water-stress studies. *Plant and Soil* **39**, 205–207.

Cai T, Zhang C, Huang Y, Huang H, Yang B, Zhao Z, Zhang J and Jia Z (2015) Effects of different straw mulch modes on soil water storage and water use efficiency of spring maize (*Zea mays* L.) in the Loess Plateau of China. *Plant, Soil and Environment* **61**, 253–259.

Dalley CD, Bernards ML and Kells JJ (2006) Effect of weed removal timing and row spacing on soil moisture in corn (*Zea mays* L.) 1. *Weed Technology* **20**, 399–409.

Finch-Savage WE and Bassel GW (2016) Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany* **67**, 567–591.

Ghanbari A, Hasani MA, Dori H and Taheri MM (2020) Study of dry and wet planting effects on grain yield of genotypes spotted bean (*Phaseolus vulgaris*) genotypes. *Iranian Journal of Crop Sciences* **4**, 59–66, (In Farsi with English abstract).

Hamza M and Anderson W (2003) Responses of soil properties and grain yields to deep ripping and gypsum application in a compacted loamy sand soil contrasted with a sandy clay loam soil in Western Australia. *Australian Journal of Agricultural Research* **54**, 273–282.

Hemmati E, Vazan S and Oveisi M (2011) Effect of pre-planting irrigation, maize planting pattern and nitrogen on weed seed bank population. *Communications in Agricultural and Applied Biological Sciences* **76**, 551–554.

Irigoyen J, Einerich D and Sánchez-Díaz M (1992) Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (*Medicago sativa* L.) plants. *Physiologia Plantarum* **84**, 55–60.

Kisekka I, Aguilar JP, Rogers DH, Holman J, O'Brien DM and Klocke N (2017) Assessing deficit irrigation strategies for corn using simulation. *Transactions of the ASABE* **59**, 303–317.

Krasensky J and Jonak C (2012) Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. *Journal of Experimental Botany* **63**, 1593–1608.

Kumar SD and Lal BR (2012) Effect of mulching on crop production under rainfed condition: a review. *International Journal of Research in Chemistry and Environment, (IJRCE)* **2**, 8–20.

Li X, Yang Y, Zhang M and Wang X (2010) Effect of PEG priming on plasma membrane H± ATPase activities and mitochondrium function in soybean seeds. *Seed Science and Technology* **38**, 49–60.

Lipiec J, Doussan C, Nosalewicz A and Kondracka K (2013) Effect of drought and heat stresses on plant growth and yield: a review. *International Agrophysics* **27**, 463–477.

Loura D, Florentine S and Chauhan BS (2020) Germination ecology of hairy fleabane (*Conyza bonariensis*) and its implications for weed management. *Weed Science* **68**, 411–417.

Nawaz MF, Bourrie G and Trolard F (2013) Soil compaction impact and modelling. A review. *Agronomy for Sustainable Development* **33**, 291–309.

Ngwira A, Aune JB and Thierfelder C (2014) On-farm evaluation of the effects of the principles and components of conservation agriculture on maize yield and weed biomass in Malawi. *Experimental Agriculture* **50**, 591–610.

Olabode O and Sangodele A (2015) Effect of weed control methods on performance of sweet corn (*Zea mays* L. saccharata) in Ogbomoso south west Nigeria. *Journal of Global Biosciences* **4**, 1145–1150.

Pittman KB, Barney JN and Flessner ML (2020) Cover crop residue components and their effect on summer annual weed suppression in corn and soybean. *Weed Science* **68**, 301–310.

Ram C, Kumari P, Singh O and Sardana R (1989) Relationship between seed vigour tests and field emergence in chickpea. *Seed Science and Technology* **17**, 169–173.

Ranaivoson L, Naudin K, Ripoche A, Rabeharisoa L and Corbeels M (2018) Is mulching an efficient way to control weeds? Effects of type and amount of crop residue in rainfed rice based cropping systems in Madagascar. *Field Crops Research* **217**, 20–31.

Rannu RP, Ahmed R, Siddiky A, Ali ASM, Ibn Murad KF and Sarkar PK (2018) Effect of irrigation and mulch on the yield and water use of residueberry. *International Journal of Agronomy* **2018**, 1–10.

Reis LSD, Pereira MG, Silva RFD and Meireles RC (2011) Efeito da heterose na qualidade de sementes de milho doce. *Revista Brasileira de Sementes* **33**, 310–315.

Scavo A and Mauromicale G (2020) Integrated weed management in herbaceous field crops. *Agronomy* **10**, 1–26.

Shen J, Zhao D, Han H, Zhou X and Li Q (2012) Effects of straw mulching on water consumption characteristics and yield of different types of summer maize plants. Plant, *Soil and Environ* **58**, 161–166.

Sinay H and Karuwal RL (2014) Proline and total soluble sugar content at the vegetative phase of six corn cultivars from Kisar Island Maluku, grown under drought stress conditions. *International Journal of Advance Agricultural Research* **2**, 77–82.

Soltani A, Robertson MJ, Torabi B, Yousefi-Daz M and Sarparast R (2006) Modelling seedling emergence in chickpea as influenced by temperature and sowing depth. *Agricultural and Forest Meteorology* **138**, 156–167.

Stelli S, Hoy L, Hendrick R and Taylor M (2018) Effects of different mulch types on soil moisture content in potted shrubs. *Water SA* **44**, 495–503.

Uwah D and Iwo G (2011) Effectiveness of organic mulch on the productivity of maize (*Zea mays L.*) and weed growth. *Journal of Animal and Plant Sciences* **21**, 525–530.

Wang X, Wu H, Dai K, Zhang D, Feng Z, Zhao Q, Wu X, Jin K, Cai D and Oenema O (2012) Tillage and crop residue effects on rainfed wheat and maize production in northern China. *Field Crops Research* **132**, 106–116.

Wayayok A, Soom MAM, Abdan K and Mohammed U (2014) Impact of mulch on weed infestation in system of rice intensification (SRI) farming. *Agriculture and Agricultural Science Procedia* **2**, 353–360.

Weisskopf P, Reiser R, Rek J and Oberholzer HR (2010) Effect of different compaction impacts and varying subsequent management practices on soil structure, air regime and microbiological parameters. *Soil and Tillage Research* **111**, 65–74.

Williams MK, Heiniger RW, Everman WJ and Jordan DL (2014) Weed control and corn (*Zea mays*) response to planting pattern and herbicide program with high seeding rates in North Carolina. *Advances in Agriculture* **21**, 2014.

Zhou X, Chen Y and Ouyang Z (2011) Effects of row spacing on soil water and water consumption of winter wheat under irrigated and rainfed conditions. *Plant, Soil and Environment* **57**, 115–121.

Zimdahl RL (2018) *Fundamentals of Weed Science*. Colorado State University: Academic Press.