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Assessment of Irrigated Cotton Seedling Emergence in Flatland Mechanized Planting Systems

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ABSTRACT

The nonuniform emergence of cotton seedlings in the flatland mechanical planting method is a major problem in cotton production areas with crust-forming soil and saline soil and irrigation water. A field study was conducted in central Iran within Isfahan Province to assess the effects of four types of planting equipment and three crust breaking methods on cotton (Varamin cultivar) emergence on a clay loam soil. Four items of planting equipment were used, consisting of: a cotton planter with runner opener and its smooth-crown zero pressure pneumatic press wheels positioned along or away from the seed row; a cotton planter with runner opener and open-center concave steel press wheels; and a grain drill with disk opener and without covering device. Three crust breaking methods were employed, including rolling cultivator, rolling-type crust breaker (two spike-tooth drums in tandem) and no crust breaking. The crust breaking operations were done one week after the first irrigation when the first seedlings had emerged. Final emergence, planting depth, plant height and soil strength were measured.The choice of planting equipment had significant effects on planting depth, final emergence and plant height. The cotton planter with its press wheels positioned along the seed row had the greatest level of seedling emergence in a non-crust breaking treatment. This is because, during the planting operation, the soil was very dry and the press wheels were firming the soil above or around the seed to the degree that enough seed-soil contact was provided and the seeding depth was decreased. In non crust-breaking treatments, the emergence was less than 50%. The difference in emergence for the rolling cultivator and the rolling-type crust breaker was not significant. However, the rolling cultivator could be recommended due to its availability in the region. Results indicated that the grain drill (with acid delinted cotton seed) or alternatively the cotton planter with open-center press wheels (with undelinted seed) could be used with the rolling cultivator as a crust breaker as a mechanized cotton dry flatland planting system in this region.

Keywords: Cotton emergence, Crust breaker, Drill, Planter, Rotary hoe.

INTRODUCTION

Seed germination and seedling emergence are influenced by several factors, these being mainly the seed, the environment, and various mechanical factors. The environment provides the basic requirements of light, heat, oxygen and moisture. The mechanical factors provide such aspects of the planting configuration as row spacing, seed placement distance, depth of sowing, seed rate, and degree of seed-soil contact. These may also modify the environmental factors (16).

The design of the furrow opener and closure mechanism on seeding implements,

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combined with soil packing, has a considerable effect on plant stand establishment and subsequent plant growth. This is due to their effects on seed placement, seed-soil contact for moisture absorption and germination (7, 12, 18), soil strength of the seed zone (21), and strength of the crust along the seed row (16).

A flat-surface rubber-tired press wheel firms and packs the soil directly above the seed, whereas an open-center concave steel press wheel firms the soil around the seed and yet leaves the soil above the seed in a loose condition to prevent crusting (10). In addition, they also perform the function of closing the seed furrow and serve as a driving unit for the metering mechanisms (5). Compaction of the soil by the planter can affect the availability of moisture and oxygen to the germinating seed, the seed zone temperature and soil water losses (25) and may cause mechanical impedance to its emergence (8,16).

Each soil type may respond in a different manner or to a different extent to a given compactive force (24). Larson *et al*. (14) showed that different soils vary widely in bulk density, initially, and also as a result of applied stress. Both an increase in water content and applied stress within the same soil, cause an increase in bulk density. These findings probably explain why press wheels are required in some soils and not in others (16).

From the field tests, Wanjura *et al*. (25) concluded that, under normal conditions, surface press wheels decreased cotton emergence in an Amarillo loam soil. Surface press wheels provided a slight increase in maximum seed zone temperature and a reduction in soil water loss. However, the compaction of surface soil reduced cotton emergence. Montemayor (16) studied the effect of a locally made drill and a planter with inclined press wheels on cotton seedling emergence. She found that press wheels fitted on planters increased soil strength around the seeds, which caused impedance to cotton emergence. It is worth to mentioning that the planting was done at high soil moisture content of 14% (pre-plant irrigated condition).

A soil crust is a thin hard layer formed on the surface of the soil due to dispersive forces in the rain drops or irrigation water followed by drying (3). The problem is more severe in soils low in organic matter (19). Soil crust offers mechanical resistance to merging seedlings. If a young seedling lacks energy to break through the crust, it bends just beneath the crust and dies. The failure of seedlings to emerge is a common problem in sandy and loamy soils of many arid and semi-arid regions of the world, where the rapid drying of soil results in a faster development of a strong soil crust. The crops that are usually affected by crusting are pearl millet, cotton, grain sorghum, soybean, carrot and other small grains (2, 9).

Once a crust is formed, it should be wetted frequently or should be broken mechanically. Application of water is often impractical due to the limited availability of water in arid and semi-arid regions, labor requirements and cost. Shallow cultivation is recommended to break the crust, which loosens the topsoil surface and leaves it open for faster infiltration of water. However, shallow cultivation cannot be used over seed rows that are ready for emergence because the cultivator may seriously damage young seedlings just below the soil crust. For crust breaking over the seed rows just before emergence, a rotary hoe (4) and a rolling-type soil crust- breaker (2) were used.

Bilbro and Wanjura (4) tried two tools, a rotary hoe and a small experimental disk device, to break surface crusts formed by simulated rain. They found that crust breaking generally enhanced emergence provided no seedling emergence had occurred through the crust at the time of breaking. Otherwise, there was significant damage to the emerging seedlings. Awadhwal and Thierstein (3) designed, developed and tested a mechanical, rolling-type soil crust breaker. They showed that the rolling-type crust breaker performed well in experimental fields. It broke the crust over seeded rows without any visible physical injury to the young

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seedlings just below the crust and improved seedling emergence significantly compared to emergence in crusted conditions (2).

Cotton planting in most regions of Isfahan is by hand broadcasting. To increase the planted areas and to economize the cotton production in the region, mechanization of the planting operation is essential. However, bed planting of cotton in the production areas with crust-forming soil and saline irrigation water is not practical. The objective of this research was to study the emergence of cotton seedlings using a flatland mechanical planting method and to improve the cotton emergence by using crust-breaking equipments after the first irrigation.

MATERIALS AND METHODS

Site and Soil

Field plot studies were conducted in 1997 at the Kabootarabad Agricultural Research Station of the Isfahan Agricultural Research Center, located 40 km southeast of Isfahan in central Iran. The topsoil (0-20 cm) at the study site had a clay loam texture. The topsoil was weakly aggregated, structureless (massive), low in organic matter (<1%) and alkaline in reaction (PH=8).

Experimental Design and Treatments

A 4×3 factorial treatment arrangement with three replications in a randomized complete block design was used. Experimental plots were 3 m wide and 20 m long with 6 m wide side headlands.

The planting treatments used were as follows.

1) Bazrsazan cotton planter (locally-made cotton or corn planter) equipped with a runner opener, 14 cm wide smooth-crown zero-pressure pneumatic press wheels along (P_1, Figure 1a) and away from (P_2, Figure 1b) the seed row.

2) John Deere planter equipped with a runner opener, open-center steel press wheels (P_3, Figure 2).

3) Nordsten (model CLGHI 250) grain drill equipped with single-disk opener, without any covering device (P_4, Figure 3).

The metering devices on both planters (Bazrsazan and John Deere) were a picker wheel (5), but the width of the picker wheel on the Bazrsazan planter was wider. The seed-metering device on the grain drill was fluted feed.

The Crust-breaking treatments employed were:

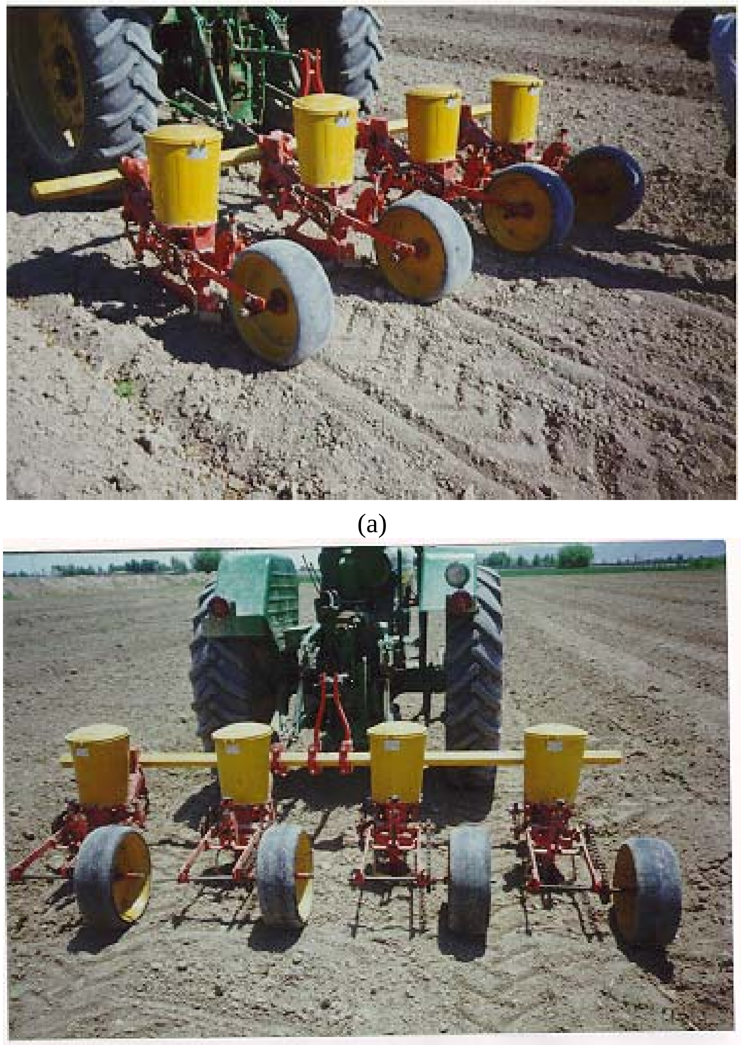
1) A rolling cultivator equipped with four tandem gangs. The centers of the front and the rear gangs were 3 cm apart. The effective width of each tandem gang was 14 cm. Each gang was set such that its twisted blades worked as backward-inclined tines and its axle was perpendicular to the direction of travel (C_1, Figure 4a),

2) Rolling-type crust breaker equipped with two spike-tooth drums in tandem (Awadhwal and Thierstein, 1983). The diameter and the length of each rolling drum were 18 and 15 cm, respectively. The spike length was 2.5 cm and the inter-row spacing of the spikes was 2.5 cm. The weight of the implement with added ballast was about 30 kg (C_2, Figure 4b).

3) No-crust breaking (C_0).

Cotton Sowing

The planting method was a dry flatland planting system. In each plot, four rows of 20 m length were planted. A cotton variety (Varamin) was seeded at the rate of 40 kg ha^{-1} with a row spacing of 80 cm. Undelinted and ash-rubbed undelinted seeds were used with Bazrsazan and John Deere planters, respectively. Preliminary tests showed that the agitator in a grain drill hopper couldn't make the undelinted cotton seeds flow toward seed-metering devices, therefore the acid delinted seeds were used in this planter. The 1000-kernel weight and the germination percentage for undelinted and



(a)

(b)

Figure 1. Bazersazan cotton planter with its press wheels along (a) and away from (b) the seed row.

delinted seed were 130 and 100 g, and 75 and 80%, respectively. The irrigation method used was flooding level basins. In this experiment, the pre-plant primary and secondary tillage operations consisted of chisel plowing and disc harrowing plus leveling, respectively.

Soil and Plant Measurements

Soil strength, final emergence, planting depth and plant height were measured. The penetrometer resistance of the soil (soil strength) along the sowing-line was measured one day before the crust-breaking operation. The soil strength was measured in 1 cm increments to a depth of 10 cm by slowly forcing the blunt 2 cm diameter tip of a hand-held Bush soil penetrometer ((SP1000) (1) into the soil. This was done at 20 positions along the middle of the sowing-lines in each plot, and the mean penetrometer resis-

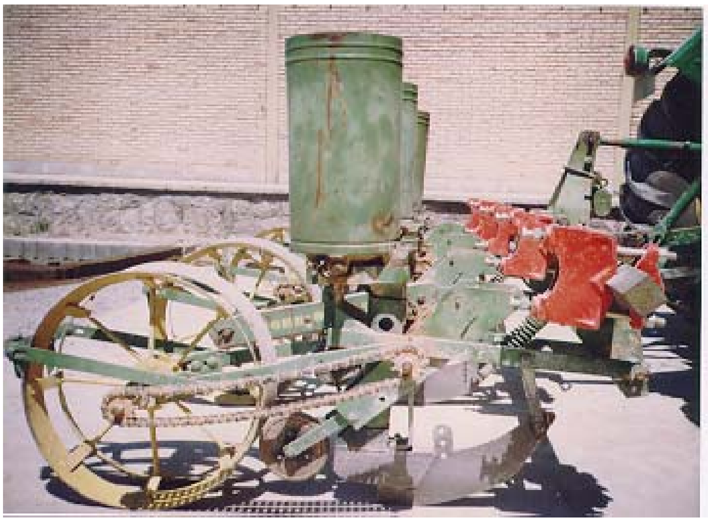


Figure 2. John Deere cotton planter with open center concave steel press wheels.

tance at each depth was calculated.

Daily plant counts were taken starting at first emergence and continuing until full emergence, in four 1 metre long seed row sections identified by stakes in each plot. The percentage of seedlings emerged (E) was calculated using the following equation

$$E = \left[\frac{N}{(P_n \times G)} \right] \times 100$$

where **N** is the number of seedling emerged per meter, $\mathbf{P_n}$ is the number of seeds planted per meter, and **G** is the germination percent (decimal). Once plant counts were completed, all seedlings that emerged within the two 1 metre long seed row sections in each plot were pulled out, and their chlorophyll-free length was measured as an indication of soil coverage (seeding depth). The plant height was measured in other two 1metre long seed row sections of each plot 35 days after planting. The height measurement of

Figure 3. Nordsten grain drill with single disk openers.

(a)

(b)

Figure 4. Crust breakers: (a) rolling cultivator and (b) manually operated rolling-type soil crust breaker.

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each plant was taken from the soil surface to the point where the branches on the main stem were initiated.

Statistical Analysis

An analysis of variance (ANOVA) for the 4×3 factorial experiment was performed to determine the significance of the treatments and interactions (20). Comparisons of the overall treatment effects were made using Duncan's new multiple range tests.

Table 1. Mean penetrometer resistance of soil along the seed row in the 0-5 and 5-10 cm layers in unbroken crust treatment as affected by different planters [a].

Planting system	Penetrometer resistance (MPa)	
	Layer 0-5 cm	Layer 5-10 cm
Cotton planter with zero pressure pneumatic press wheel along the seed row (P_1)	0.52 a[b]	0.72 a
Cotton planter with zero pressure pneumatic press wheel away from the seed row (P_2)	0.28 c	0.68 a
Cotton planter with open-center concave steel press wheel (P_3)	0.46 ab	0.68 a
Drill without covering device (P_4)	0.35 bc	0.62 a

[a] Measurements were made seven days after irrigation. Note: The means of moisture content in the 0-5 and 5-10 cm layers were 12 and 19% (dry basis), respectively.
[b] Means followed by the same letter in each column are not significantly different according to Duncan's new multiple range test at the 5% level of probability.

RESULTS AND DISCUSSION

Planting System Effects on Soil Strength

The effect of the planting system (the combined effect of furrow opener and press wheel of the planter) on soil strength in the 0-5 and 5-10 cm. layers in unbroken crust treatment is shown in Table 1. The effect was significant in the first layer, but not in the second layer. Analysis of penetrometer resistance data in 1 cm layers showed that the effect of planting system on soil strength was only significant in the first three 1 cm layers. Hence, the press wheel is similar to the packer roller and its effect is limited to the seed zone. In the first layer (0-5 cm), the press wheel along the seed row (P_1) and away from the seed row (P_2) had the highest and the lowest compaction, respectively. The soil strength measured in the P_2 treatment shows the soil strength created in the seed zone only by the furrow opener used on row crop planter. Therefore, the press wheels on the P_1 and P_3 planters increased soil strength in the seed zone by 73 and 53%, respectively. Stephens and Johnson (21) showed the planting systems on the row crop planters could provide a soil strength in the seed zone ranging from 30 to nearly 200% of the original soil strength by using adjustments and standard accessories.

Although the press wheel on the planter (P_2) was away from the seed row and the drill (P_4) had no covering device, the soil strength created by P_4 in the seed zone was still 17% greater. The difference was proba-

Table 2. Analysis of variance (mean squares) for planting depth, final emergence and plant height.

Source of variation	Degree of freedom	Planting depth	Final emergence	Plant height
Replication	2	0.22	237.25	570.93
Planting system (A)	3	2.95*	2183.81**	494.92*
Crust-breaking method (B)	2	0.73	2245.58**	350.17
A× B	6	0.32	217.17	251.06
Error	22	0.46	143.19	252.57
Total	35			

*, ** Indicate significant effects at probability levels of 0.05 and 0.01, respectively.

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Table 3. Effect of the planting system and crust-breaking method on planting depth, final emergence and plant height.

Treatments	Planting depth (cm)	Final emergence (%)	Planting height (cm)
Planting system:			
Cotton planter with zero pressure pneumatic press wheel along the seed row (P_1)	3.9 b[a]	50 a	93.4 ab
Cotton planter with zero pressure pneumatic press wheel away from the seed row (P_2)	5.2 a	34 b	79.9 b
Cotton planter with open-center concave steel press wheel (P_3)	4.4 b	62 a	93.4 ab
Drill without covering device (P_4)	4.0 b	53 a	97.7 a
Crust breaking method:			
Crust not broken (C_0)	4.3 A	35 B	84.2 A
Crust broken with rotary hoe (C_1)	4.2 A	61 A	91.8 A
Crust broken with rolling-type crust breaker (C_2)	4.2 A	54 A	95.4 A

[a] Means followed by the same letter for each factor in each column are not significantly different according to Duncan's new multiple range test at the 5% level of probability.

bly due to the fact that the furrow opener on the drill was disk type, whereas on the planter it was runner type. The disk opener is a backward inclined tine and provides more reconsolidation.

Planting System Effects on Seedling Emergence

The overall effects of the planting system and crust breaking method on seedling emergence were significant, but their interaction was not (Table 2). Therefore, the effect of each factor on seedling emergence could be studied separately. There were no significant differences in emergence between the treatments P_1, P_3 and P_4, but the percentage of emergence of P_2 was significantly lower than in the other treatments (Table 3). Therefore, the cotton planters with their press wheels positioned along the seed row had the most seedling emergence in non-crust breaking treatments. This was due to the fact that, during the planting operation, the soil was very dry and the press wheels were firming the soil around the seed to the degree that enough seed-soil contact was provided and the seeding depth was decreased (Table 3). The soil strength (in the 0-5 cm. layer) and sowing depth measurements confirmed this result. It was observed that moderate compaction by wheeled traffic may improve seed germination and seedling establishment (13). It is also well known that moderate compaction above the seed enhances seed germination owing to better seed-soil contact which facilitates water absorption and closes or disturbs the continuity of larger pores thereby preventing the airflow from moving freely to seed depth and drying the new rootlet (8). The latter is especially important in the hot dry conditions encountered by spring-sown crops (such as cotton) in the climate of central Iran. Additionally, firm soil provides a good medium for anchoring the root and helping the shoot to emerge through the soil.

On the contrary, Montomayor (16) reported a strong depression in seedling emergence (>50%) with the press wheels of the planter on the seed row. Decreased seedling emergence was due to the high soil strength around the seeds that caused impedance to cotton emergence. In her experiment, the cotton was planted after the applied preplant irrigation had dried to about 14% soil moisture content; however, in this experiments, the planting was done in dry condi-

Table 4. Seedling emergence from four planting systems as affected by three crust breaking methods.

Planting System	Crust breaking method		
	Crust not broken (C_0)	Rotary hoe (C_1)	Rolling-type (C_2)
	--------- Emergence (%) ---------		
Cotton planter with zero pressure pneumatic press wheel along the seed row (P_1)	45 a[a]	55 a	49 b
Cotton planter with zero pressure pneumatic press wheel away from the seed row (P_2)	24 c	46 b	33 c
Cotton planter with open-center concave steel press wheel (P_3)	43 ab	73 a	70 a
Drill without covering device (P_4)	27 bc	69 a	65 a

[a] Means followed by the same letter in each column are not significantly different according to Duncan's new multiple range test at the 5% level of probability.

tions. In addition, the press wheels on her planter were inclined and very narrow whereas, in this experiment, the press wheels were wide and they were of the zero pressure pneumatic or open-center concave type.

Although the planting depth on all planters was set at 4 cm, the planter P_2 planted the seed significantly deeper (Table 3). This was due to locating the press wheel away from the seed row on this planter and, hence, the soil along the seed row was not pressed down. Increasing seeding depth increased the heat requirement for emergence (6), emergence time (17), and the time for 50% emergence (15, 22), in addition to decreasing the emergence rate (11).

Crust Breaking Method Effects on Seedling Emergence

Crust breaking had a significant effect on emergence (Table 2). In non crust-breaking treatments, the emergence was less than 50%. The comparison of the percentage of emergence for P_2, P_3 and P_4 treatments in non-crust-breaking (C_0) and crust-breaking treatments (C_1, C_2), primarily showed the failure of seed to emerge rather than the failure of seeds to germinate (Table 4). Therefore, the crust formed over the seed rows did not allow the seedling to emerge. Although the performance of the rotary hoe (C_1) was better than the rolling-type crust breaker (C_2), their emergence percentages were statistically equal (Table 4). Bilbro and Wanjura (4) reported that the rotary hoe was superior to the small-disk device only when the crust-breaking operation was delayed until some seedlings had already emerged. Awadhwal and Thierstein (2) showed that the rolling-type soil crust breaker could improve seedling emergence significantly in millet and sorghum.

The rotary hoe (C_1) was more effective in breaking the crust on P_2 treatment plots than the rolling-type crust breaker (C_2) (Table 4). This was due to the fact that the depth of penetration of the spike on the C_2 crust breaker was low (the length of each spike was just 2.5 cm.) and the weight on its frame was not sufficiently large.

Planting System Effects on Plant Height

The plant height in the P_2 and P_4 treatments were the lowest and highest, respectively (Table 3). The plants with the “press wheels away from the seed row” (P_2) treatment were shorter (79.9 cm) than those plants in the treatment with the “press wheels on the seed row” (P_1) (93.4 cm). This shows that even those plants which emerged have been under stresses that affected their growth. It appears that increasing planting depth decreased the plant growth rate. This

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effect lasted for 35 days after the initial planting. Hucl and Baker (11) reported that increasing the planting depth from 3 to 6 cm delayed seedling emergence and, in particular, reduced and delayed the emergence of the coleopilar and the first leaf tillers of wheat. Tamet *et al.* (23) also found that poor seed placement control affects not only emergence but also early growth for carrot.

CONCLUSIONS

The results of these experiments can be summarized as follows.

1) The choice of planting system and crust breaking had significant effects on the final cotton emergence.
2) In the non-crust breaking treatments, the cotton planter with press wheels along the seed row had the greatest seedling emergence.
3) The difference in emergence between the rolling cultivator and the rolling-type crust breaker was not significant, however the rolling cultivator could be recommended due to its availability in the region.
4) The grain drill (with acid delinted cotton seed) or, alternatively, the cotton planter with open-center press wheels (with un-delinted seed) with a rotary hoe as a crust breaker could be used as a mechanized cotton dry flatland plant system in the region.

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ارزيابي سبز شدن پنبه آبي در سيستم هاي كشت مكانيزه مسطح

ع. همت، ا. ا. خشويي و ا. رنجبر

چكيده

يكي از مشكلات جدي در توليد پنبه در خاك‌هاي حساس به سله، آب آبياري و خاك شور، سبز شدن نايكنواخت گياهچه‌هاي پنبه در روش كشت مكانيزه مسطح مي باشد. در يك آزمايش مزرعه‌اي در ايران مركزي در استان اصفهان، اثر چهار ماشين كاشت و سه روش سله‌شكني بر سبز شدن پنبه رقم ورامين، در يك خاك با بافت لوم رسي بررسي شد. ماشين‌هاي كاشت شامل رديف كار پنبه با شياربازكن كفشكي و مجهز به چرخ فشار بدون باد رويه-لاستيكي صاف در امتداد و خارج از امتداد رديف كاشت، رديف كار پنبه با شياربازكن كفشكي و مجهز به چرخ فشارفولادي دو قسمتي (ميان خالي) و خطي كار با شيار بازكن ديسكي و بدون پوشاننده بذر، و سه روش سله شكني شامل كولتيواتور غلتان، سله شكن غلتان (دو استوانه دندانه‌دار كه پشت سر هم قرار دارد) و روش بدون سله شكني بودند. سله‌شكني يك هفته پس از اولين آبياري و با ظهور اولين گياهچه‌ها انجام شد. درصد سبز نهايي، عمق كاشت، ارتفاع گياه و

مقاومت خاك اندازه‌گيري شد. ماشين كاشت اثر معني‌داري بر عمق كاشت، درصد سبزشدن و ارتفاع گياه داشت. در تيمار بدون سله شكني، رديف كار پنبه در حالتي كه چرخ فشار آن روي رديف كاشت حركت نمود، بيشترين درصد سبز شدن را داشت. دليل آن، اين بود كه در زمان كاشت به علت خشكي خاك، چرخ‌هاي فشار خاك را در بالا يا اطراف بذر بحدي فشرده نمودند كه تماس كافي بين بذر و خاك تامين شد و عمق كاشت نيز كاهش يافت. در تيمارهاي بدون سله شكني، درصد سبز شدن كمتر از ۵۰ درصد بود. هرچند بين درصد سبز شدن در روش‌هاي سله شكني با كولتيواتور غلتان و سله شكن غلتان تفاوت معني داري مشاهده نشد، ولي سله شكني با كولتيواتور غلتان كه در منطقه موجود است را مي‌توان پيشنهاد نمود. نتايج نشان داد كه كاشت پنبه با خطي كار (با بذر بدون كرك) يا رديف كار پنبه مجهز به چرخ فشار دوقسمتي (با بذر كركدار) همراه با سله شكني با كولتيواتور غلتان را مي توان به عنوان سيستم كاشت مكانيزه بذر پنبه در روش خشكه كاري در كشت مسطح در منطقه پيشنهاد نمود.

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