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Comparative Performance of Four Planter Furrow Opener and Row Cleaner Arrangements in a Conservation Tillage Corn Production System

N. SANAVI SHIRI[1*], M. H. RAOUFAT[1]**

[1]Dept. of Agricultural Machinery, College of Agriculture, Shiraz University, Shiraz, I. R. Iran

ABSTRACT- A study was conducted to compare the performance of four types of planter furrow opener and row cleaner arrangements at two crop residue levels on the amount of surface residues after planting, seeding depth, emergence rate index and seed spacing indices of corn in a soil covered with previous wheat residue. Residue levels were baled out and non-baled (untouched). Corn was planted with a planter equipped with the following furrow openers and attachment arrangements: double disc furrow opener preceded by a row cleaner (DR), chisel furrow opener preceded by a row cleaner (CR), winged chisel furrow opener preceded by a row cleaner (WCR) and winged chisel furrow opener without row cleaner (WC). Results showed that WCR treatment at baled out residue level retained the least amount of residue on the seed row after planting. Measurements showed that residue level for all treatments were higher than the residue level required for establishing conservation tillage practices. An increase of ERI up to 15% was obtained for this treatment as compared to CR and WC treatments. Double disc furrow opener preceded by row cleaner treatment resulted in higher percentage of ERI as compared to CR and WC, possibly due to less planting depth. The study showed increasing depth is more influenced by furrow opener shape than the amount of bed residue. The lowest miss index was obtained for WCR treatment at baled out residue level which is desirable. Improvement in quality of feed index was found to be 36% for WCR treatment when compared to planting with DR and WC treatments. Furthermore, this treatment decreased the value of precision index up to 45% as compared to DR and WC treatments.

Keywords: Conservation tillage, Furrow opener type, Row cleaner, Crop residue and Residue management

INTRODUCTION

Crop residue management is a key component of conservation tillage. Conservation tillage is defined to be any tillage/planting system which leaves at least 30% of the field covered with previous crop residue after planting has been completed (18). Maintaining crop residue on the soil surface rather than baling, burning or tilling offers many benefits. Provision of more plant nutrients and higher levels of organic matter in the soil, increase in soil water content and decrease in wind and water erosions are just a few of the advantages of crop residue management (4). These tillage systems not only reduce erosion and improve the soil environment for crop growth, but also conserve energy and decrease the labor cost of farming (30). In recent years, no-till crop production systems

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[*]Former Graduate Student and Associate Professor, respectively
[**]Corresponding Author

were identified as a major practice to reduce greenhouse gas (carbon) emissions from agriculture (15).

In spite of the advantages, conservation tillage increases the risk of poor stand establishment and therefore limits its adoption by farmers (2, 33). Current seeding implements are often inadequate in untilled soils under the various soil and crop residue conditions encountered in conservation tillage practices (10). For instance, the performance of no-tillage seeders depends on several factors related to field conditions, including type and amount of residues on the soil surface, opener design and the crop to be sown (20). In no-tillage practices, the characteristics of the seed-furrow play an important role in germination. Many researchers have pointed out that the most significant factors regulating germination, such as soil matric potential, temperature (14, 25) and sowing depth (1, 16) are affected by the soil/opener interaction.

Many characteristics of seed zone in no-till depend on the type of opener attached to the seeder. The two main types used; tine and disk may lead to great differences (35). The tine opener typically creates an appreciable bursting effect in the soil and generally moves a considerable quantity of fine damped aggregates towards the soil surface, a fact particularly appreciable in tools having an asymmetric shape (7). However, it may not be true if a rainless period occurs after sowing, as soil drying is accelerated (6). In similar conditions, the disk opener may cause more progressive water loss in the soil layer above the seeds than the tine opener (28, 29); although great drawbacks are observable in wet clay soils because a permanent unclosed furrow is commonly created (24).

Regarding soil and climate conditions, openers should achieve several aims; uniformity of sowing i.e., seed spacing and depth, production of a suitable amount of fine soil aggregate to ensure soil/seed contact, reduction of water losses, avoidance of seed contact with either fertilizers or crop residues and limitation of furrow compaction, which may impede root growth (3, 31, 36). The type of opener was found to affect emergence and plant establishment markedly (19). Chaudhry and Baker (5) found that various types of opener led to different patterns of growth of barley seedlings, i.e., greater shoot and root weights when both winged (T-shaped groove) or hoe (U-shaped groove) types are used instead of the triple-disk one.

Surface residues decrease planting depth and uniformity and increase the number of seeds placed closer to the surface. Poor corn stand establishment, large variations in seed depth and uneven emergence have been shown to decrease corn grain yield or at least to limit yield potential (22). Neither burning crop residue nor conservation techniques including no-tillage, ridge tillage, or strip tillage can satisfy farmers and authorities both. Reduced tillage systems and modification of existing planters may be necessary for successful operations. In order to overcome the seed placement problems in conservation tillage systems, Raoufat & Matbooei (22) and Fallahi & Raoufat (9) suggested equipping row-crop planters with row cleaner attachments. Row cleaners cleaned the trash on the row, helping to improve seed placement uniformity in conservation tillage system.

Penetration of furrow openers in hard soils is a problem especially for disc-type openers when sowing under stubble mulch conditions, due to the tendency of the opener to push dry soil and stubble into the furrows. As alternatives, under zero tillage conditions, furrow openers, such as chisel, winged chisel and inverted T, shatter the subsurface residue resulting in better plant emergence rate and final stand (6).

The management of previous wheat residue has become a major problem for corn producers in Iran (22). Several factors, ranging from the lack of management decisions for handling crop residues to the inability of conventional planters to drill corn into soils covered with residue are contributing to the problem.

The objective of the present study was to compare the effects of three types of row crop planter furrow openers preceded by row cleaner and a furrow opener without row cleaner on the amount of surface residue after planting operation, emergence rate index (ERI), seeding depth and indices of plant spacing when cropping maize after a wheat harvest in a conservation corn production system.

MATERIALS AND METHODS

As mentioned earlier, furrow openers can play an important role in providing proper seed placement depth especially under minimum tillage conditions. Therefore, in this study three types of furrow opener were used; double disk, chisel and winged chisel. Considering the results of previous studies (6, 17 and 26), a chisel and a winged chisel furrow opener were fabricated. The design of furrow openers is basically concentrated on their optimum rake angle. Rake angle is denoted by the angle which the furrow opener makes with a horizontal line parallel to the direction of travel (6). Considering the results of previous studies (6, 17, 26) in which the values of the rake angle for lowest draught is usually around 25^o-30^o, a winged chisel and a chisel furrow openers with a 30^o rake angle were designed and fabricated from high carbon steel plates 5 mm thick. The winged chisel had two 5-cm width bottom beveled wings which were angled downward 45^o (Fig. 1). The front blade could cut soil 25-30 mm deeper than the wings. The winged chisel furrow opener was bolted to the steel shank which was hitched to a single-row pneumatic single seed type row-crop planter frame with bolt and nut combination.

A row cleaner attachment was installed in front of the furrow opener to clean rows from previous residue. It was made of two 16 cm diameter free rotating tine wheels placed at a 45^o angle against each other. Row cleaner assembly comprised of a pivot joint and a spring loaded link, providing suitable floatation (Fig. 2).

Field experiments were established in summer 2007 at the Badjgah Research Station, Shiraz University located in NW Shiraz, Iran. The soil composed of 20.6% sand, 46% silt and 33.3% clay and was classified as clay-loam covered with previous irrigated wheat crop residue at an average moisture content of 8% db at the depth range of 0–20cm. The wheat was harvested by a combine harvester leaving relatively uniform stubble. The average residue mass before tillage operation for non-baled (untouched) and baled-out (partially removed) residue levels were 6.75 and 4.5 t ha^{-1}, respectively. A split-plot experiment arranged as a randomized complete block design was conducted with four replications. The main treatment was previous wheat residue in two levels: non- baled residues (NB) and baled out (B). The sub-treatment was a planter with four types of furrow openers and row cleaner arrangements: double disc furrow opener preceded by a row cleaner attachment (DR), chisel furrow opener preceded by a row cleaner attachment (CR), winged chisel preceded by a row cleaner attachment (WCR), and winged chisel without row cleaner attachment (WC).

Fig 1. Winged chisel (left) and chisel (right) furrow openers used in the study

Fig 2. Winged chisel furrow opener preceded by row cleaner attachment

Operation prior to planting was limited to only twice disk harrowing. The disc harrow used was an offset 24 blade 90 cm diameter disc harrow with notched discs on the front gang and plain discs on the rear gang. Its working width and depth were 2.46 m and 0.06 m, respectively. Four rows of hybrid Corn SC-704 with thousand kernel weight of 250 g, emergence rating of 85% and purity of 98% were planted with a single row multi-purpose pneumatic row crop planter. The rows spacing and theoretical seed spacing were 75 cm and 10 cm, respectively. Plot dimensions were 5 by 20 m and the measurements/counting taken in each plot were weight of the residue before and after tillage and after planting operations, depth of seed placement, number of seeds emerged per day and the distance between consecutive seedlings. Planting operation speed was maintained at 7 km h^{-1} for all treatments.

Residue Management Technique

The quantity of wheat residue was measured after harvest and before tillage by collecting, drying at 105° C for 24 h and weighing all surface residuesfrom a 0.5 m^2 quadrant using 10 samples for each plot. The average amounts of irrigated wheat residue at this experimental site were 6.75 and 4.5 t ha^{-1} for non baled and baled out plots, respectively.

Measurements after tillage showed 4.65 and 2.4 t ha^{-1} of crop residue retained for non-baled and baled-out plots, respectively. After planting, residue was measured using 2 samples $0.5\times$ 0.37 m frame for each row. The least amount of residue on the rows was 1.48t ha^{-1} (Table 1). Equation (1) introduced by Pependick (21) was used to convert flat surface cover to percent residue cover:

$$Y = (1 - e^{-0.000644\,X}) \times 100 \quad (1)$$

Where

Y is the percentage of residue cover

X is the dried weight of residue per unit surface area, lb $acre^{-1}$

The goal for conservation purposes is to have at least 30% of the soil surface covered with crop residue (18). The equation was solved for 30% surface residue cover and *X* was found to be 554 lb $acre^{-1}$ which is equal to 621 kg ha^{-1}. Therefore, for conservation purposes, the surface residue should not be less than 621 kg ha^{-1}. The amount of residue retained on each plot before and after tillage and after planting operations was markedly more than 621 kg ha^{-1} needed to establish conservation farming practices (Table 1).

Seed Placement Depth

A special tube with 53-mm inside diameter and 120-mm height with one sharpened edge was used to extract several seedlings from the soil in each row to measure placement depth. The seedlings were washed and the length of the mesocotyl was measured. An extra 2 cm was added to obtain seed placement depth since nodal roots typically grow approximately 2 cm below the soil surface (23).

Emergence Rate Index (ERI)

For each treatment an ERI was determined (Eq. 2) by counting the number of plants emerged from a mid-5 m length of rows for several days after planting (DAP) using the following equation introduced by Erbach (8):

$$ERI = \sum_{n=1}^{x} \frac{EMG_n - EMG_{n-1}}{DAP_n} \quad (2)$$

Table 1. The effect of residue condition and planter furrow opener and attachment on surface residue, seeding depth and emergence rate index

Parameter	Planter furrow opener and attachment	Residue amount		
		NB*	B	Mean
Surface reside ($t\ ha^{-1}$)	DR†	2.39 a‡	1.76 c	2.07 A♀
	CR	2.30 a	1.70 c	2.00 B
	WCR	2.05 b	1.48 d	1.76 C
	WC	2.39 a	1.77 c	2.08 A
	Mean	2.29A	1.68 B	
Seeding Depth (cm)	DR	4.29 e	4.67 d	4.49C
	CR	4.82 bc	4.97 a	4.9A
	WCR	4.92 ab	4.98 a	4.95A
	WC	4.72 cd	4.92 ab	4.82B
	Mean	4.69 B€	4.89 A	
ERI ($\%d^{-1}$)	DR	13.02 c	14.08 b	13.55B
	CR	11.51 d	13.26 c	12.38C
	WCR	14.03 b	15.15 a	14.59A
	WC	11.50 d	13.18 c	12.34C
	Mean	12.52 B	13.92 A	

****Residue condition: NB, non-baled; B, baled and removed**
***Planter furrow opener and attachment: DR, double disc furrow opener preceded by row cleaner; CR, chisel furrow opener preceded by row cleaner; WCR, winged chisel furrow opener preceded by row cleaner; WC, winged chisel furrow opener without attachment.**
‡for each parameter, means followed by the same letters are not significantly different at P<0.01
♀for each parameter, means within each column followed by the same capital letters are not significantly different at P<0.01
€for each parameter, means within each row followed by the same capital letters are not significantly different at P<0.01 (DNMRT)

where n is the nth emergence observation, EMG_n is the percentage of seeds planted emerged on the day of the nth emergence observation, EMG_{n-1} is the percentage of seeds planted emerged on the day of the (n-1)th emergence observation, equal to 0 when n=1 and DAP_n is the number of days after planting when the nth emergence observation was taken. In this study, counts were made on 7, 9, 11, 13, 15, 18, and 21 and 25 days after planting, and stopped when no further increase in emerged counts was observed.

Uniformity of Seed Spacing

The uniformity of seed spacing was determined by using ISO standards (1984) based on the theoretical spacing (X_{ref}) for the planter as outlined by Katchman and Smith (13). Observed plant spacing at several locations was divided by X_{ref} to create five categories: [0, $0.5x_{ref}$], ($0.5X_{ref}$, $1.5X_{ref}$], ($1.5X_{ref}$, $2.5X_{ref}$], ($2.5X_{ref}$, $3.5X_{ref}$], and ($3.5X_{ref}$, ∞) which corresponded to the following classifications: (1) a multiple, closer to the previous plant than the theoretical spacing; (2) a single, closer to the theoretical spacing than either the previous plant or a single skip; (3) a single skip, closer to a single skip than either the theoretical spacing or a double skip, (4) as a double skip, and (5) as a triple or more skips. The seeds that fall into the second classification are considered as planted with correct spacing. Seeding indices were calculated according to Kachman and Smith (13). These were quality of feed index, miss index, and precision index. The quality of feed index is the percentage of spacings that are more than half but no more than 1.5 times the theoretical spacing. Larger values of quality of feed index indicate better planter performance than smaller values. In other words, the quality of feed index is a measure of how often the spacings are close to the theoretical spacing (13). The number of seeding distances placed in the range of $(1.5X_{ref}, \infty)$ was divided by the total number of planted seeds to obtain the percentage of miss index (13). Smaller values of this index indicate better performance than larger values. For example a miss index of 15%, means that 15% of the observed plants were viewed as 'having at least a single skip' among them. These skips could be due to a number of factors including the failure of the planter to drop a seed or the failure of the seed to germinate or produce a seedling. With the theoretical spacing of 10 cm in this study, the miss index is the percentage of spacing that are greater than 15 cm. Precision index is a measure of the variability in spacings between plants after accounting for variability due to both multiples and skips. For each treatment this index was obtained by dividing the standard deviation of distances in the range of $(0.5X_{ref}\ 1.5Xref)$ by X_{ref}. Smaller values of this index indicate better performance of the planter than larger values. This index measures the degradation of performance within the target range (13).

RESULTS AND DISCUSSION

Surface Residues after Planting Operation

Analysis of variance of the data on surface residues retained after planting operation indicated that both the amount of residue before planting and type of planter furrow opener and attachment arrangements and also their interaction had significant effects on this factor ($p<0.01$).

Comparison of the means of data on the amount of surface residues retained after planting operation (Table 1) showed that winged chisel furrow opener preceded by row cleaner attachment retained the lowest amount of residues on the seed row after planting. It is particularly true for baled-out residue plots. No significant difference among means of retained residue for other treatments was noticed (Table 1).

According to McCarthy et al (18) 621 kg ha^{-1} of residue cover equal to 30% surface residue for small grains such as wheat is needed to establish a soil conservation system. In the present study, all of the data on surface residues were well above this base line. Considering that surface residues retard the emergence and early growth of corn by slowing soil warming (11, 27, 32), it is advisable to use a planter equipped with a winged chisel furrow opener preceded by row cleaner in conservation farming.

Effect on Seeding Depth

Analysis of variance of the data on seeding depth indicated that both the amount of residue before planting and types of planter furrow opener and cleaner attachment arrangement and also their interaction had significant effects on this factor ($p<0.01$).

Comparison of means of seeding depth (Table 1) indicated that the lowest seeding depth was obtained by double disc furrow opener preceded by row cleaner (DR) treatment. Table (1) also shows that WCR, CR and WC treatments do not significantly differ in this factor and these treatments exhibit equally higher seeding depths close to the target depth (0.06 m) as compared to DR treatment. The improvement in seeding depth might be due to the shapes of the furrow openers. In other words tine furrow openers could penetrate better than disc shaped ones. For the DR treatment seeding depth was further decreased when planting on higher residue plots but other treatments did not follow the same trend.

Emergence Rate Index

Analysis of variance of the data on emergence rate index indicated that both the amount of residue after planting and type of planter furrow opener-cleaner arrangements and also their interaction had significant effects on this factor ($p<0.01$).

Table (1) shows that the highest ERI ($15.15\%d^{-1}$) is obtainable on plots planted with winged chisel preceded by row cleaner at baled out residue conditions. On the other hand, the lowest ERI ($11.5\%d^{-1}$) was obtained for winged chisel furrow opener (WC) and also chisel furrow opener preceded by row cleaner (CR) at non-baled residue conditions. Therefore, improvement on ERI can be achieved up to 15%, provided that proper planter attachment is used on reduced residue farms. In general planting at baled out residue level improved ERI up to 12% as compared to non-baled residue level (Table 1). This finding is in agreement with that of Wick et al (34) who stated that higher surface residue causes further reduction in soil temperature and thus slower emergence.

Effect on Seeding Indices

During field trials, it was observed that the degree of residue cover and width of cleaned row affect seed spacing. As expected, higher surface residue and smaller cleaned width hampered press wheel rotation resulting in unsatisfactory performance of seed metering system for most treatments envisaged for this study.

Effect on quality of feed index

Analysis of variance of the data on quality of feed index indicated that both the amount of residue before planting and type of planter opener-cleaner arrangement and also their interaction had significant effects on this factor ($p<0.01$).

Comparison of means of feed index (Table 2) indicates that winged chisel furrow opener preceded by row cleaner (WCR) has the highest value of quality of feed index for both residue conditions, as compared to other treatments. Average overall improvement of 49% in the quality of feed index was noticed for the winged chisel furrow opener preceded by row cleaner treatment as compared to DR and WC treatments regardless of residue conditions. Other data show that an improvement in the quality of feed index up to 26% can be obtained when planting on baled-out residue plots regardless of type of opener-cleaner arrangement as compared to non-baled residue plots.

Comparing the pairs of data on the mean surface residue retained after planting operation (Table 1) and the mean quality of feed index (Table 2) reveal that the quality of feed index increases when planting on soils with low surface residue conditions. The reason is the positive rotation of planter press wheel in soils with less residue cover. Similar results have been reported by Kaspar and Erbach (12) who stated that crop residue interferes with planter performance resulting in poor seed placement and reduced final stand.

Effect on miss index

Analysis of variance of the data on miss index indicated that both the amount of residue before planting and planter opener-cleaner arrangement and also their interaction had significant effects on this factor ($p<0.01$).

The comparison of means of miss index indicated that the lowest value of this index was obtained for WCR treatment regardless of residue level (Table 2). The value of miss index for WCR treatment on baled-out residue plots was nearly half the non-baled ones. The reason is the lower residue on the row after planting operation resulting in a more positive rotation of planter press wheel and satisfactory performance of seed metering system. A close look at the amount of residue retained on the row area for DR and WC treatments and their respective miss index revealed that planting with lower miss index is fairly possible on low residue plots, something which is desirable (Table 1, 2).

Table 2. Influence of residue condition and planter furrow opener and attachment on seed indices

Parameter	Planter furrow opener and attachment	Residue amount **		
		NB	B	Mean
Quality of Feed index (%)	DR	36.64 f‡	50.02 d	43.33 C♀
	CR	47.82 e	58.82 c	53.32 B
	WCR	60.25 b	69.01 a	64.63 A
	WC	36.75 f	50.78 d	43.76 C
	Mean	45.37 B€	57.16 A	
Miss index (%)	DR	44.58 a	21.73c	33.16 A
	CR	33.25 b	19.21c	26.23 B
	WCR	21.36 c	10.83d	16.09 C
	WC	43.84 a	21.66c	32.75 A
	Mean	35.76 B	18.36A	
Precision (%)	DR	28.95 a	19.45cd	24.20 A
	CR	23.67 bc	16.75d	20.75 B
	WCR	15.47 de	10.75e	13.11 c
	WC	27.72ab	19.00cd	23.36 A
	Mean	23.96B	16.47A	

****Residue condition: NB, non-baled; B, baled and removed**
***Planter furrow opener and attachment: DR, double disc furrow opener preceded by row cleaner; CR, chisel furrow opener preceded by row cleaner; WCR, winged chisel furrow opener preceded by row cleaner; WC, winged chisel furrow opener without attachment.**
‡for each parameter, means followed by the same letters are not significantly different at P<0.01
♀for each parameter, means within each column followed by the same capital letters are not significantly different at P<0.01
€ for each parameter, means within each row followed by the same capital letters are not significantly different at P<0.01 (DNMRT)

Effect on precision index

Analysis of variance of the data on precision index indicated that both the amount of residue before planting and planter opener-cleaner arrangement and also their interaction had significant effects on this factor ($p<0.01$).

The comparison of means of precision index (Table 2) indicates that winged chisel furrow opener preceded by row cleaner (WCR) has the lowest value of the precision index for baled-out residue level which is desirable. Moreover, this treatment decreased the value of the precision index up to 45% as compared to DR and WC treatments regardless of residue conditions. The findings emphasize the improvement of residue management for obtaining satisfactory seed spacing (Tables 1and 2).

CONCLUSIONS

A practical solution to residue management in a minimum tillage system is outlined. The possible impact of this research is that farmers can benefit from advantages of a reduced tillage system by modifying their existing planters. In addition to the environmental benefits of the proposed system, it is expected that the savings in time, fuel and labor would offset the cost of row cleaners and winged chisel furrow openers.

The specific conclusions drawn from the present study are:

1. An alternative to no till corn production is the minimum tillage system that can be adopted by disc harrowing twice and using existing planters equipped with winged chisel furrow opener preceded by row cleaner attachment. By this way, extra residues are removed from the row area and appropriate residue levels are maintained for soil conservation purposes.
2. Tine furrow openers (Winged chisel and chisel) could successfully plant seed on high residue plots at desirable depth, whereas a double disk furrow opener could not place seeds in the targeted planting depth mainly due to heavy residues.
3. The findings emphasize that seed placement depth is more influenced by the opener's shape than the amount of residue on the seedbed.
4. With appropriate residue management, desirable values of emergence rate, miss, quality of feed and precision indices were obtained using existing planters equipped with a winged chisel furrow opener preceded by cleaner attachment.

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مقایسه اثرات چهار نوع آرایش شیاربازکن و ضمیمه ردیف تمیزکن ردیف کار در کاشت ذرت در خاک ورزی حفاظتی

نسیبه ثانوی شیری[1*] محمد حسین رئوفت[1]**

[1]بخش مکانیک ماشین های کشاورزی دانشکده کشاورزی دانشگاه شیراز، شیراز، جمهوری اسلامی ایران

چکیده– در پژوهش حاضر کارایی چهار نوع آرایش شیاربازکن و ضمیمه ردیف کار در دو سطح بقایا بر مقدار بقایای گیاهی سطحی پس از انجام عملیات کاشت، عمق کاشت، شاخص سرعت جوانه زنی، شاخص های فاصله کاشت بذر به هنگام کاشت ذرت در بقایای گندم مورد بررسی قرار گرفت. بقایا شامل دو سطح جمع آوری شده و دست نخورده بود. آرایش شیاربازکن و ضمیمه کارنده شامل؛ شیار بازکن های دو بشقابی به همراه ضمیمه ردیف تمیزکن (DR)، شیاربازکن چیزل به همراه ردیف تمیزکن (CR)، شیاربازکن چیزل باله دار به همراه ردیف تمیزکن (WCR) و چیزل باله دار بدون ضمیمه(WC) بودند. نتایج نشان دادکه تیمار شیار بازکن چیزل باله دار به همراه ضمیمه ردیف تمیزکن در سطح بقایای بسته بندی و از مزرعه خارج شده، کمترین مقدار بقایای گیاهی را بر سطح خاک باقی گذاشته است. لازم به ذکر است که در تمامی تیمارها میزان بقایای گیاهی بالاتر از حد توصیه شده برای برقراری حالت حفاظتی بود. افزایش معادل ٪۱۵ در شاخص سرعت جوانه زنی برای این تیمار در مقایسه با تیمارهای CR و WC حاصل گردید. شیاربازکن دوبشقابی به همراه ردیف تمیزکن در مقایسه با CR و WC منجر به درصد بالاتری از شاخص سرعت جوانه زنی شد، احتمالا علت این امر عمق کاشت کمتر در این تیمار می باشد. سایر نتایج مطالعه حاضر نشان داد که افزایش عمق کاشت در یک کارنده بیشتر تحت تاثیر شکل شیاربازکن می باشد تا میزان بقایا. کم ترین مقدار شاخص نکاشت هنگام کاشت با شیار بازکن چیزل باله دار به همراه ردیف تمیزکن در سطح بقایای جمع آوری شده حاصل گردید که مطلوب می باشد. کاشت با کارنده مجهز به شیاربازکن چیزل باله دار به همراه ردیف تمیزکن در مقایسه با کاشت توسط کارنده مجهز به شیاربازکن دو بشقابی به همراه ردیف تمیزکن موجب افزایش شاخص کیفیت تغذیه به میزان ٪ ۳٦ و کاهش شاخص دقت به میزان ٪٤٥ گردید.

واژه های کلیدی: خاک ورزی حفاظتی، شیار باز کن، ردیف تمیز کن، بقایای گیاهی و مدیریت آنها

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[*] به ترتیب دانشجوی پیشین کارشناسی ارشد و دانشیار
[**] مکاتبه کننده