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RESEARCH TITLE

EFFECT OF INTRA AND INTER-ROW SPACING ON YIELD AND YIELD COMPONENTS OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) UNDER ZERO TILLAGE

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Abstract

A field experiment was conducted during two seasons 2013/14 and 2014/15 in Demonstration Farm of the Arab Sudanese Blue Nile Agricultural Company in Blue Nile State to study the effect of intra-row and inter-row spacing on yield and yield components of sunflower under zero tillage system . It comprised three intra-rows spacing 20, 30 and 40 cm, and three inter-rows spacing 60, 80 and 100 cm .The experiment was laid out in a factorial randomized complete block design with three replications. Data were collected to measure head diameter (cm), percentage of empty seed, number of full seed, numbers of seeds/ head, head yield (g) , 1000 seeds weight (g) and seed yield (ton/ ha). The result showed that, intra-row spacing showed significant effect on head diameter (cm), number of full seed, number of seeds/ head, head yield (g) and seed yield (ton/ ha). Inter-row spacing revealed significant effect on head diameter (cm), number of full seed, number of seeds/ head and head yield (g). The interaction between intra-row spacing and inter-row spacing showed significant effect on head diameter (cm), number of full seed ,numbers of seeds/ head, head yield (g),1000 seeds weight (g) and seed yield (ton/ ha).

Key Words: zero tillage system; inter row spacing, intra row spacing, and sunflower.

Introduction

Sunflower (*Helianthus annuus* L.) belongs to the family (Compositae). Originated in North America, the genus Helianthus is formed of both annual as herbaceous and perennial species. Sunflower hybrids grown in the country contain from 39 to 52 % oil in the seed and still have better yield potential. Sunflower seed was the third largest sources of vegetable oil worldwide, following cotton seed and soybean, sunflower oil is generally considered a premium oil because of its light color, high level of unsaturated fatty acids and lack of linolenic acid, bland flavor an high smoke points, the primary fatty acids in the oil are oleic and linolenic (Typically 90 % unsaturated fatty acids), with the remainder consisting of palmatic and stearic saturated fatty acids (Anon.,1987). Sunflower was introduced into Sudan in 1932 by Gezira research station. It was tried as a summer crop in 1951 and failed due to its low fertilization (Khidir, 1997).Generally Sunflower plant grows well in areas which receive annual rainfall of 750 mm. Weiss (1983) reported that Sunflower plant can grow well in a temperature range of about 20-25 ˚C . In Sudan Sunflower was recently introduced to diversify the cropping system in rainfed (Gedarif, Damazine, Kadugli) and irrigated Gezira, Rahad, El suki and Halfa Schemes (Ahmed *et al.*, 1997).

Zero tillage defined as direct seeding without plowing or harrowing, using chemical treatment for weed control before and during the growing season. Zero-tillage system has been selected to replace the traditional system.

In Sudan Osman (1989/90), tested sunflower at two row spacing (60 and 80cm) and three intra-row spacing (20, 30 and 40 cm) and found no significant differences in yield. However, the closer row spacing (60cm) and the 20 cm intra – row gave better yields, while the yield of 60x30 cm spacing was better than spacing 40x20 cm and 60x20 cm by about 12% and 5.5% respectively. Bindra and Kharwara (1992) in India reported that, the spacing of 45x20cm recorded significantly the highest seed yield over 60x20 cm and 30x20 cm spacing. The author attributed the significantly higher yield of spacing 45x20 to increased head diameter and 1000 seed weight, in an attempt to determine the optimum growing density for sunflower.

Kgvacik and Skaloud (1988) in Czechoslovakia recommended a plant density of

less than 60000 plants/ha under favorable conditions on lighter soil with less water and nutrient, though a density of 69230 plants/ha gave the maximum yield. Tianu *et al*. (1981) in Romania, reported that, the cultivars Romsum and Florem produced highest yields at a plant density of 50000 plants/ha. In contrast, Mora and Tatter (1987) in Chile, reported that the best yield was obtained from plant density of 80000 plants/ha under dry land conditions.

Cruz and Dela (1989) stated that head diameter revealed significant variations among sunflower hybrids. In study of 36 genotypes of sunflower for 10 agronomic characters, a considerable variation was reported among genotypes for most of the characters including head diameter (Chervet and Vear, 1990). Haken *et al*. (2003) in evaluation of twenty sunflower genotypes showed that, the genotypes differed significantly in the entire characters investigated including head diameter except for kernel percentage. Kandil and Al-Mohandis (1986) reported that, the head diameter was significantly correlated with the seed yield per plant. Abdel-Aal (1992) indicated that, the seed yield was strongly and positively with head diameter. Arshad *et al*. (2007) stated that head diameter had positive direct effect on seed yield.

Human *et al*., (1990) stated that the severe stress during anthesis and seed filling stage resulted in more empty seeds. Khidir, (1997) reported that, one of the major problems of sunflower production in the Sudan is the high percentage of empty seeds in non-hybrids and to a lesser extent in the hybrid sunflower genotypes. Poparlan, (1987) in study of 42 genotypes of 20 species, indicated that the percentage of empty seeds of wild species varied from 20.8 to 53 %. Hedge and Havanagi (1989) stated that, the moisture stress during the late flowering stage decreased the number of filled seeds and stress during seed filling stage decreased seed weight.

Hedge and Havanagi (1989) stated that the moisture stress during the late flowering stage decreased the number filled seeds and stress during seed filling stage decreased the seed weight. Zaffaroni and Sclemeter (1991) stated that number of seeds per head had the greatest direct effect on the yield. Chervet and Vear (1990) indicated that the seeds number per head appeared to be important than the 1000 seed weight.

Patil *et al*., (1996) reported that, the analysis of variance revealed significant

genotypic differences for all characters studied in sunflower genotypes; the range of variation was a maximum for number of seeds per head, followed by weight of head and seed yield. Kshirsagar *et al*., (1995) reported, the variations among the genotypes were greater for seed yield /plant followed by plant height, number of seeds/head and 1000 seed weight.

Mirza *et al*., (1997) reported significant genetic and phenotypic variability for 1000 seed weight in sunflower. Kanna (1972) indicated that the problem is further complicated by the fact that, 1000 seed weight varies considerably even within the same variety. Steer *et al*., (1986) found that, 1000 seed weight decrease by increasing plant population. Bindra and Kharwara (1992) in India ,reported that the spacing of 45×20 cm recorded significantly the highest seed yield over 60 ×20 cm and 30×20 cm spacing .The authors attributed the significantly higher yield of spacing 45×20 to increased head diameter and 1000 seed weight.

It is a quantitative character controlled by many genes and is influenced by the environment. Wang *et al*., (1997) found that a wide range of variability in number of seeds /plant, seed yield /plant and seed weight. Karmi, (1977) stated that, reduction in seed yield occurred in wider spacing than in closer ones. El- Hity (1994) reported that, the open pollinated cultivars gave higher seed yields than introduced hybrids. Cruz and Dela (1989) reported that, the yield /plant had highly significant variation among hybrids.

Weiss (1983) reported different ranges for sunflower yield averages all over the world 1.5 -3.0 (t/ha) in Australia, 2.0-3.0 (t/ha) in Chile, Brazil and Argentina, 0.5-3.0 (t/ha) in India and less than 0.5 (t/ha) in Africa. Khalifa (1981) found a significant variation in seed yield of sunflower cultivars depending on the system of farming and cultural practices. Mahmood and Mehdi (2003) found that, significant differences among S1and S2 progenies evaluated for seed yield in sunflower. Chervet and Vear, (1990) stated that for the components directly determining yield; seed number/head appear to be more important than 1000 seed weight. Zafforni *et al*., (1991) stated that number of seed /head had the greatest direct affect on yield.

Materials and Methods:

A field experiment was conducted for two consecutive seasons (2013/14 and 2014/15) to study the effect of intra and inter row spacing on growth of sunflower (*Helianthus annuus* L.) under Zero tillage conditions. The Experiment was carried out at the Demonstration Farm of the Arab Sudanese Blue Nile Agricultural Company, Blue Nile State, Sudan about 500km South from Khartoum (Latitude 11°.4′ - 12° .2′ N Longitude 34°.39′- 35°.90′ E and Altitude 580 meters above sea level). Soil at the site is heavy clay soil. The climate of locality is semi arid with mean annual rainfall of about 600-900 mm and with maximum temperature of about 37 C° in summer and around 21.6 C° in winter (El hag, 2013). Data on temperature and relative humidity in each season were obtained from the Damazine Metrological Station.

A factorial experiment was laid out in A Randomized Complete Block Design with three replicates. The seeds of sunflower (Sarina) obtained from Switch Company for Agricultural Services. The treatment consist of three intra row spacing 20,30 and 40 cm designated as WR1,WR2 and WR3 respectively, and three inter row spacing 60,80 and 100 cm. Designated as BR1, BR2 and BR3 respectively.

The land where the experiment was conducted was divided into plots. The size of individual plot was 5×3 meters consisting of five rows, 5 meters in length and rows spacing was 70 cm, after the weeds was germinated and appear at the top of the soil we applied by glyphosate at rate 1 L/F, and we also used pre-emergence herbicides (Stomp) at rate 0.8 L/F to prevent the germination of grasses, we used knapsack sprayer. Seeds were sown in rows; the crop was sown on the first week of July in both seasons and zero tillage system was used.

Results and Discussions:

Intra-row spacing showed significant difference on head diameter (cm) in the second season only. Inter-row spacing showed significant effect on stem diameter (cm) in both seasons. In addition, the interaction between intra-row and inter-row spacing showed significant effect on head diameter (cm) in both seasons, where the highest level of head diameter (cm) was given by the combination WR3×BR3 in the second season and the lowest level of head diameter (cm) was given by the combination

WR2×BR1 in the first season (Table 1). This result in agreement with Hakan *et al*. (2003) who stated that, sunflower genotypes differed significantly on head diameter; therefore, increasing the spacing within plants in row gave higher stem diameter (cm).

Intra-row spacing showed no significant difference on percentage of empty seed (%) in both seasons. Inter-row spacing showed no significant effect on percentage of empty seed (%) in both seasons. Moreover, the interaction between intra-row and inter-row spacing showed significant effect on percentage of empty seed (%) in the second season only, where the highest percentage of empty seed (%) was given by the combination WR3×BR3 in the second season and the lowest percentage of empty seed (%) was given by the combination WR3×BR1 in the first season (Table 2). Human *et al*. (1997) stated that, the severe stress during anthesis and seed filling stage resulted in more empty seeds. Khidir (1997) reported that, one of the major problems of sunflower production in the Sudan is the high percentage of empty seeds in non-hybrids and to a lesser extent in the hybrids sunflower genotypes.

Intra-row spacing showed significant difference on number of full seed in both season. Inter-row spacing showed significant effect on number of full seed in the first season only. Moreover, the interaction between intra-row and inter row showed significant effect on number of full seed in both season, where the highest number of full seed was given by the combination WR3×BR3 in second season only and the lowest number of full seed was given by the combination WR1×BR1 in the first season (Table 3). These results disagreed with Osman (1989/1990) in Sudan while testing sunflower at two row spacing (60 and 80 cm) and three intra-row spacing (20,30 and 40cm) he reported that, there were no significant differences in yield. However, the closer row spacing (60 cm) and 20 cm intra-row gave better yields. The yield of 60×30 cm spacing was better than 42×20 cm spacing.

Intra-row spacing showed significant difference on number of seeds/head in the second season only. Inter-row spacing showed significant effect on number of seeds/head in the first season only. Moreover, the interaction between intra-row and inter row showed significant effect on number of seeds/head in the first season only, where the highest number of seeds/head was given by the combination WR3×BR3 in

both seasons and the lowest number of seeds/head was given by the combination WR1×BR1 in the first season (Table 4), these results agreed with Kshirsagar *et al*. (1995) who reported that, there were significantly increased the seed yield by increasing the number of seeds /head .The variation among the genotypes were greater for seed yield /plant followed by number of seeds /head. The numbers of seeds/head were increased by increasing the intra- row spacing within the plant.

Intra-row spacing showed significant difference on head yield (g) in both seasons. Inter-row spacing showed significant effect on head yield (g) in the second season only. The interaction between intra-row and inter-row spacing showed significant effect on head yield(g) in both seasons, where the highest head yield(g) was given by the combination WR3×BR2 in the second season and the lowest head yield(g) was given by the combination WR1×BR1 in the first season (Table 5), these results agreed with Wang *et al*. (1997) who found, optima wide range of variability in head yield, and it's a quantitative character controlled by many genes and is influenced by. The result disagreed with Karmi (1977) who stated that, reduction the environment in seed yield occurred in wider spacing than in closer ones. Khalifa (1981) found significant variation in head yield of sunflower cultivars depending on system of farming and cultural practices. The seed yield decreased as intra-row spacing was increased.

Intra-row spacing showed no significant difference on 1000 seeds weight in both seasons. Inter-row spacing showed no significant effect on 1000 seeds weight in both seasons. The interaction between intra-row spacing and inter-row spacing showed significant difference on 1000 seeds weight in the second season only, where the highest 1000 seeds weight was given by the combination WR2×BR3 in the first season and the lowest 1000 seeds weight was given by the combination WR1×BR1 in the first season (Table 6). These results disagreed with Mariza *et al*. (1987) who reported that, there were significant genetic and phenotypic variability for 1000 seeds weight in sunflower. Kanna (1972) indicated that, the problem is further complicated by the fact that, 1000 seed weight varies considerably even within the same variety.

Intra-row spacing showed a significant effect on seed yield (ton/ ha) in both

seasons. Inter-row spacing showed significant effect on seed yield in the second season only. The interaction between intra-row spacing and inter-row spacing showed significant difference on seed yield in both seasons, where the highest seed yield was given by the combination WR1×BR1 in the second season and the lowest seed yield was given by the combination WR1×BR3 in the first season (Table 7). These results disagreed with Weiss, (1983) who reported different ranges for sunflower yield averages all over the world 1.5 -3.0 (t/ha) in Australia, 2.0-3.0 (t/ha) in Chile, Brazil and Argentina, 0.5-3.0 (t/ha) in India and less than 0.5 (t/ha) in Africa.

Table (1): Effect of intra-row, inter-row spacing and their interaction on head diameter (cm) of sunflower (2013/14 and 2014/15) seasons

Season 2013/14					Season 2014/15				
Treatment	WR1	WR2	WR3	**Mean**	Treatment	WR 1	WR2	WR3	**Mean**
BR1	15.39^{c}	15.28^{c}	16.33^{bc}	**15.67^{b}**	BR1	19.31^{e}	19.89^{e}	20.89^{d}	**20.03^{c}**
BR 2	16.43^{bc}	16.45^{bc}	17.43^{ab}	**16.77^{a}**	BR 2	21.78^{c}	22.77^{b}	23.11^{b}	**22.55^{b}**
BR 3	17.00^{ab}	18.21^{a}	18.44^{a}	**17.88^{a}**	BR 3VB	23.32^{b}	24.52^{a}	24.73^{a}	**24.19^{a}**
Mean	**16.27^{a}**	**16.65^{a}**	**17.4^{a}**		**Mean**	**21.47^{b}**	**22.39^{a}**	**22.91^{a}**	
LSD		1.488			LSD		0.6265		
C.V.		5.12 %			C.V.		1.63 %		

* Means within the same column followed by the same letters are not significantly different

Key:

LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter-row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter-row) 100 cm

Table (2): Effect of intra-row, inter- row spacing and their interaction on percentage of empty seeds (%) of sunflower (2013/14 and 2014/15) seasons

Season 2013/14					Season 2014/15				
Treatment	WR 1	WR2	WR3	**Mean**	Treatment	WR1	WR2	WR3	**Mean**
BR1	5.71[a]	5.95[a]	5.50.[a]	**5.72[a]**	BR1	6.05[d]	6.49[bcd]	6.53[bcd]	**6.36[a]**
BR 2	5.71[a]	5.85[a]	5.96[a]	**5.84[a]**	BR 2	6.34[cd]	7.23[abc]	7.32[ab]	**6.96[a]**
BR 3	5.85[a]	5.99[a]	6.24[a]	**6.03[a]**	BR 3	6.73[bcd]	7..18[abc]	7.75[a]	**7.22[a]**
Mean	**5.76[a]**	**5.93[a]**	**5.90[a]**		**Mean**	**6.37[a]**	**6.97[a]**	**7.2[a]**	
LSD		1.217			LSD		0.9559		
C.V.		12.04 %			C.V.		8.06 %		

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LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter-row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter-row) 100 cm

Table (3): Effect of intra-row, inter-row spacing and their interaction on number of full seed of sunflower (2013/14 and 2014/15) seasons

Season 2013/14					Season 2014/15				
Treatment	WR1	WR2	WR3	**Mean**	Treatment	WR 1	WR2	WR3	**Mean**
BR1	975^{c}	984^{c}	1077^{b}	**1012^{b}**	BR1	1167^{b}	1225^{a}	1133^{b}	**1175^{a}**
BR 2	1091^{b}	1038^{b}	1166^{a}	**1098.33^{a}**	BR 2	1214^{a}	1127^{b}	1228^{a}	**1189.67^{a}**
BR 3	1120^{b}	1148^{a}	1287^{a}	**1185^{a}**	BR 3	1009^{c}	1243^{a}	1238^{a}	**1163.33^{a}**
Mean	**1062^{b}**	**1056.67^{a}**	**1176.67^{a}**		**Mean**	**1130^{b}**	**1198.33^{a}**	**1199.67^{a}**	
LSD		140.6			LSD		25.43		
C.V.		6.92 %			C.V.		12.01 %		

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Key:

LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter row) 100 cm

Table (4): Effect of intra-row, inter-row spacing and their interaction on number of seeds /head of sunflower (2013/14 and 2014/15) seasons

	Season 2013/14					Season 2014/15			
Treatment	WR 1	WR2	WR3	**Mean**	Treatment	WR 1	WR2	WR3	**Mean**
BR1	1035de	1047^{e}	1140^{bcde}	**1074^{b}**	BR1	1242^{a}	1310^{a}	1212^{a}	**1254.67^{a}**
BR 2	1157^{bcde}	1103^{cde}	1240^{abc}	**1166.67^{b}**	BR 2	1296^{a}	1215^{a}	1325^{a}	**1278.67^{a}**
BR 3	1190^{bcd}	1260^{ab}	1373^{a}	**1274.33^{a}**	BR 3	1082^{a}	1339^{a}	1343^{a}	**1254.67^{a}**
Mean	**1127.33^{a}**	**1136.67^{a}**	**1251^{a}**		**Mean**	**1206.67^{b}**	**1288^{a}**	**1293.3^{a}**	
LSD	140.6				LSD	25.43			
C.V.	6.92 %				C.V.	12.01 %			

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Key:

LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter row) 100 cm

Table (5): Effect of intra-row, inter- row spacing and their interaction on head yield (g) of sunflower (2013/14 and 2014/15) seasons

		Season	**2013/14**				**Season**	**2014/15**	
Treatment	WR 1	WR2	SR3	**Mean**	Treatment	WR 1	WR2	WR3	**Mean**
BR1	32.47^{c}	54.25^{ab}	59.08^{ab}	**48.6^{a}**	BR1	78.23^{d}	87.31^{cd}	105.5^{abc}	**90.35^{b}**
BR2	45.13^{bc}	55.99^{ab}	68.69^{a}	**56.60^{a}**	BR 2	85.52^{cd}	109.3^{ab}	123.8^{a}	**106.21^{a}**
BR3	50.99^{abc}	54.48^{ab}	68.41^{a}	**57.96^{a}**	BR3	91.28^{bcd}	121.7^{a}	122.80^{a}	**111.93^{a}**
Mean	**42.86^{b}**	**54.91^{a}**	**65.39^{a}**		Mean	**85.01^{b}**	**106.10^{a}**	**117.37^{a}**	
LSD		21.49			LSD		20.47		
C.V.		22.83 %			C.V.		11.50 %		

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Key:

LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter-row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter-row) 100 cm

Table (6): Effect of intra-row, inter-row spacing and their interaction on 1000 seeds weight (g) of sunflower (2013/14 and 2014/15) seasons

Season 2013/14					Season 2014/15				
Treatment	WR 1	WR2	WR3	**Mean**	Treatment	WR 1	WR2	WR3	**Mean**
BR1	65.35[a]	65.43[a]	73.53[a]	**68.10[a]**	BR1	68.77[ab]	68.12[ab]	74.77[ab]	**70.55[a]**
BR 2	74.66[a]	79.53[a]	76.10[a]	**76.76[a]**	BR2	74.67[ab]	79.68[ab]	74.95[ab]	**76.43[a]**
BR 3	74.19[a]	81.88[a]	69.83[a]	**75.30[a]**	BR 3	73.03[ab]	81.28[a]	67.04[b]	**73.78[a]**
Mean	**71.40[a]**	**75.61[a]**	**73.15[a]**		**Mean**	**72.16[a]**	**76.36[a]**	**72.25[a]**	
LSD		17.02			LSD		13.56		
C.V.		13.40 %			C.V.		10.64 %		

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Key:

LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter-row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter-row) 100 cm

Table (7): Effect of intra-row, inter-row spacing and their interaction on seed yield (ton/ ha) of sunflower (2013/14 and 2014/15) seasons

Season 2013/14					Season 2014/15				
Treatment	WR 1	WR2	WR3	**Mean**	Treatment	WR 1	WR2	WR3	**Mean**
BR1	1.62[b]	2.01[a]	1.92[a]	**1.85[a]**	BR1	2.34[a]	2.24[a]	2.10[b]	**2.23[a]**
BR 2	1.59[b]	1.87[a]	1.95[a]	**1.80[a]**	BR 2	1.90[b]	2.00[b]	2.20[a]	**2.03[b]**
BR 3	1.51[b]	1.69[b]	2.14[a]	**1.78[a]**	BR 3	2.20[b]	1.89[c]	2.21[a]	**2.10[b]**
Mean	**1.57[b]**	**1.86[a]**	**2.00[a]**		**Mean**	**2.15[a]**	**2.04[b]**	**2.17[a]**	
LSD		0.43			LSD		0.11		
C.V.		1.96 %			C.V.		2.01 %		

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Key:

LSD: Least significant difference
CV: Coefficient of variation
WR1: Within row (Intra-row spacing) 20 cm
BR1: Between row (Inter-row) 60 cm
WR2: Within row (Intra-row spacing) 30 cm
BR2: Between row (Inter row) 80 cm
WR3: Within row (Intra-row spacing) 40 cm
BR3: Between row (Inter row) 100 cm

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