Effect of variety and planting density on growth and yield of chickpea (*Cicer arietinum* L.) in northern Sudan

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ABSTRACT

An experiment was conducted for two seasons (2009/10 and 2010/11) at Hudeiba Research Station Farm to study the effects of variety and planting density on growth and yield of irrigated chickpea. Two chickpea varieties, namely, Hawata (semi- erect) and FLIP-98- 55C (erect) were sown in mid November in each season at five planting densities, *viz:* 17, 22, 33, 44 and 66 plants/m^2 (1.7 x 10^5, 2.2 x 10^5, 3.3 x 10^5, 4.4 x 10^5 and 6.6 x 10^5 plants/ha). The treatments were arranged in a randomized complete block design with three replicates. The results showed that Hawata was significantly earlier in number of days to 50 % flowering than FLIP- 98- 55C by 17 and 11 days, whereas, *FLIP- 98- 55C* was 17 cm and 20 cm taller with respect to the first season and 19 cm and 20 cm with respect to the second season than variety Hawata. Hawata highly significantly ($P \leq 0.001$) out-yielded FLIP-98- 55C by 53 % and 110 % in the first and second seasons, respectively, due to larger number of seeds and higher yield per plant than FLIP-98-55C, however, FLIP- 98- 55C gave higher 100- seed weight in both seasons than Hawata. On the other hand, planting density of 33 plants/m^2 significantly ($P \leq 0.05$) resulted in the highest seed yield of chickpea on both seasons. In conclusion, the highest seed yields were obtained by the two varieties at 33 plants/m^2.

INTRODUCTION

Worldwide, chickpea (*Cicer arietinum* L.) is the third most important grain legume and human dietary food after common bean (*Phaseolus vulgaris* L) and dry pea (*Pisum sativum* L.).The total cultivated area of this

this crop was estimated at twelve million hectares, producing eleven million tons of seeds shared by India, Pakistan, Spain, Turkey, Mexico, Canada, and Australia (FAO, 2010).

The seeds of chickpea are very rich in proteins (13 to 33 %) and carbohydrates (40 to 55%), in addition to some essential minerals and vitamins and therefore, the crop is a valuable human food as well as a feed and fodder for small ruminants. Moreover, chickpea fixes about 140 kg N/ha from the atmosphere through symbiotic relationship with the *Rhizobium* bacteria and hence, it is suitable as a rotational crop in cereal based cropping systems (Gan *et al.*, 2007).

In Sudan, chickpea is the third most important grain legume after faba bean (*Vicia faba* L) and kidney bean (*Phaseolus vulgaris* L.), but, its price was often higher than both leguminous crops in Ramadhan. In the past, most of chickpea cultivated area is concentrated in northern Sudan, mainly on basins and islands along the River Nile with small areas in east and west of Sudan. Recently, chickpea cultivation is extended from the north to central Sudan and new areas were annually cultivated in the Gezira irrigated scheme. However, farmers in the traditional and new areas use low yielding landraces and adopted poor cultural practices and accordingly, obtain low yields of chickpea.

In fact, the importance of the improved cultural practices in increasing chickpea yield was well known and reported by several research workers. For example, Gan *et al*. (2003) in Canada stated that chickpea seed yield was positively associated with planting density and the cultivar growth habit or canopy architecture, and reported that the optimum plant population for kabuli chickpea types ranged from 40 to 45 plants/m^2. Also, seed yield of bushy lines of chickpea was higher than erect ones (Rubio *et al*. 2005). In contrast, Saxena (1987) in Syria found that the yield of a tall up-right growing chickpea genotype was significantly increased as plant population was raised from 33 to 50 plants/m^2. Furthermore, Regan e*t al*. (2003) reported that high seed yield of chickpea was obtained at planting density ranging from 25 to 35 plants/m^2.

In Sudan, the research work in the past focused more on chickpea breeding aspects rather than cultural practices and up to date, chickpea cultivars (3 semi- erect and 5 erect) were released (Shiekh Mohammed, 1996). Yet, limited research work had been conducted on variety and plan-

ting density effects on chickpea in Sudan. Furthermore, some of the findings were not conclusive and need further testing. For example, the inter- and intra-plant spacing for seed production in the irrigated chickpea were 60 and 5 cm, respectively, with a single plant per hole as reported by Salih (1979). Also, maximum chickpea seed yield was obtained by sowing the crop on the top of 60 cm ridges at 10 cm-distance between holes with two seeds per hole (Ibrahim, 1996). Conversely, Taha (1990) found no significant differences in chickpea seed yield between 33 and 44 plants/m^2at Hudeiba Research Farm in northern Sudan.

The present study was, therefore, undertaken to evaluate the effects of variety and planting density on growth and yield of chickpea in the River Nile State, northern Sudan.

MATERIALS AND METHODS

An experiment was conducted for two seasons (2009/10 and 2010/11) at Hudeiba Research Station Farm, latitude 17˚ 34´ N, longitude 33˚ 56´ E, altitude 355 masl. The site lies in the semi desert climate of northern Sudan. The treatments consisted of two chickpea varieties having different growth habits, namely, Hawata (semi-erect) and FLIP-98-55C (erect) and five planting densities *viz*: 17, 22, 33, 44 and 66 plants/m^2(170000, 220000, 330000, 440000 and 660000 plants/ha). Variety Hawata was released by the Agricultural Research Corporation of Sudan in 1998 due to its high yield potential, whereas, FLIP-98-55 C was introduced from the International Center for Agricultural Research in the Dry Areas (ICARDA), chickpea breeding program. It has relatively large seeds and erect growth habit. The four planting densities: 22, 33, 44 and 66 plants/m^2 were achieved by sowing more than three seeds/hole on the top and on both sides of 60 cm apart ridges and 15 cm spacing between holes, thinned to two plants/hole to get the densities 22 and 44 plants/m^2 and at 10 cm intra-row spacing for the 33 and 66 plants/m^2.The fifth planting density (17 plants/m^2) was achieved by sowing on the top of the ridge at 10 cm intra-row spacing with one plant left per hole after thinning. The treatments were arranged in a randomized complete block design with three replicates. The experimental plot size was 15 m^2 (3 m wide and 5 m long). Planting date was done in mid November in each season. The experiment was irrigated every 7 to10 days and nitrogen fertilizer was applied at a rate of 20 kg N/ha as urea before the third irrigation. Weeds were controlled by hand hoeing as necessary.

Data for number of days to 50 % flowering and 90 % maturity, plant height and height from soil surface to the first pod were recorded from ten plants randomly selected from each plot, while seed yield was determined from the whole plot area (15 m^2). The yield components (number of pods, number of seeds and seed yield per plant) were recorded from ten plants randomly selected at harvest from the inner three ridges and the 100- seed weight was determined by taking random samples of 100 seeds from the final harvest and weighed. Data were analyzed using MSTATC soft package and Duncan Multiple Range Test was used for means separation.

RESULTS AND DISCUSSION

Growth and development

Variety had highly significant ($P \leq 0.001$) effects on days to 50 % flowering and days to 90 % maturity in the two seasons (Table 1). Hawata variety was earlier by 17 and 11 days than FLIP-98-55C in the first and the second seasons, respectively. Such a result partially agreed with the finding of Saban (2007) who found that semi- erect chickpea line was earlier than an erect one.

Planting density on the other hand, had slightly significant effects on days to 50 % flowering in both seasons and on days to 90 % maturity in the first season only (Table 1). Such results partially agreed with those of Valimohammedi *et al*. (2007) who stated that days to maturity in chickpea was decreased with increased planting density.

The interaction effects of variety and planting density were significantly different on the two parameters, indicating that the two varieties had different responses in days to 50 % flowering and 90 % maturity to the planting densities used (Table 2).

Variety significantly affected plant height and height to the first pod in the two seasons (Table 3). Variety FLIP-98-55C was 17 cm and 20 cm taller with respect to the first season and 19 and 20 cm with respect to the second season than variety Hawata. Similar results were reported by Vanderpuye

(2010) who found that an erect chickpea cultivar was taller and had longer distance from soil surface to first pod than semi- erect one.

Table 1. Main effects of variety and planting density on days to 50 % flowering and 90 % maturity of chickpea grown at Hudeiba Research Station Farm during season 2009/10 and 2010/11.

Treatments	Days to 50 % flowering		Days to 90 % maturity	
	Seasons			
Variety	2009/10	2010/11	2009/10	2010/11
Hawata	47	50	103	101
FLIP-98-55C	64	61	105	103
Planting density (plants/m^2)				
17	57 a	58 a	103 c	102
22	57 a	56 ab	104 ab	102
33	55 b	56 ab	104 ab	102
44	55 b	54 bc	105 a	103
66	54 b	53 c	104 ab	102
C.V. (%)	4.1	3.7	1.4	1.0

Means with the same letter (s) within each column are not significantly different at 0.05 probability level according to Duncan's Multiple Range Test.

Table 2. Interaction effects of variety and planting density on number of days to 50 % flowering and 90 % maturity of chickpea grown at Hudeiba Research Station Farm in season 2009/10 and 2010/11.

Treatments	Days to 50 % flowering		Days to 90 % maturity	
	Season 2009/10			
	Variety			
Planting density (plants/m^2)	Hawata	FLIP-98-55C	Hawata	FLIP-98-55C
17	47	67 a	102 c	104 b
22	48	66 ab	103 c	105 b
33	48	61 c	105 b	103 c
44	45	65 abc	102 c	105 b
66	45	63 bc	103 c	106 a
	Season 2010/11			
17	50	65 a	101 c	102 b
22	50	62 ab	101 c	103 b
33	51	61 b	103 b	101 c
44	48	59 bc	101 c	104 a
66	49	56 c	101 c	103 b

Means in each column(s) followed by the same letter (s) are not significantly different according to Duncan's Multiple Range Test at 0.05 level.

Planting density, however, had slightly significant effects on plant height in the second season only (Table 3). Such a result did not agree with that of Rahemi and Soltani (2005) who reported that taller plants and longer distance from the soil surface to the first pod in chickpea resulted from increased planting density and the authors attributed such a result to competition of chickpea plants for light at high planting density.

Table 3. Main effects of variety and planting density on plant height and height to first pod of chickpea grown at Hudeiba Research Station Farm during season 2009/10 and 2010/11.

Treatments	Plant height (cm)		Height to first pod (cm)	
	Seasons			
	2009/10	2010/11	2009/10	2010/11
Variety				
Hawata	56	47	31	28
FLIP-98-55C	73	67	50	48
Planting density (plants/m^2)				
17	62	56 b	39	37
22	62	57 ab	40	39
33	65	58 a	41	38
44	66	56 ab	40	39
66	62	56 b	42	38
C.V. (%)	2.6	2.1	3.7	2.4

Means in each column(s) having the same letter (s) are not significantly different according to Duncan's Multiple Range Test at 0.05 probability level.

The interaction effects of variety x planting density on both characters were significant in the two seasons (Table 4). Plant height of FLIP-98-55C was comparable at all planting densities used, however, those of Hawata varied significantly with planting density. A similar trend was also observed for the height to the first pod in both seasons.

Table 4. Interaction effects of variety and planting density on plant height and height to first pod of chickpea grown at Hudeiba Research Station Farm in season 2009/10 and 2010/11.

Treatments	Plant height (cm)		Height to first pod (cm)	
	Season 2009/10			
	Variety			
Planting density (plants/m^2)	Hawata	FLIP-98-55C	Hawata	FLIP-98-55C
17	52 c	71	29 d	49 b
22	58 b	72	32 c	48 b
33	56 bc	73	29 d	52 a
44	58 b	74	29 d	49 b
66	53 bc	75	33 c	49 b
	Season 2010/11			
17	43 d	68 a	27 c	47
22	46 c	67 a	28 b	47
33	47 c	68 a	28 c	48
44	47 c	65 b	29 b	48
66	47 c	64 b	28 c	49

Means in each column(s) followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at 0.05 levels.

Yield components

Both variety and planting density significantly affected number of seeds per plant and the 100- seed weight in the two seasons (Table 5). Hawata variety gave higher number of seeds per plant than FLIP-98-55C*;* however, FLIP-98-55C gave heavier 100- seed weight than Hawata. Increasing planting density on the other hand, from 17 to 44 plants/m^2 decreased number of seeds per plant and slightly increased the 100- seed weight (Table 5). These results agreed well with Gan *et al.* (2003) and disagreed with those of Nasibeh *et al.* (2010) who reported that planting density did not significantly affect number of seeds/plant and 100- seed weight and according to those authors, 100- seed weight was the most stable yield component and variation in this character was due to genetic factors. However, Miguelez and Valenciano (2005) reported that seed weight of chickpea was significantly decreased with increased planting density.

Table 5. Main effects of variety and planting density on number of seeds per plant and 100- seed weight of chickpea grown at Hudeiba Research Station Farm in seasons 2009/10 and 2010/11.

Treatments	Number of seeds/plant		100- seed weight (g)	
	Seasons			
	2009/10	2010/11	2009/10	2010/11
Variety				
Hawata	76	84	22	21
FLIP-98-55C	44	49	32	31
Planting density (plants/m^2)				
17	91a	94 a	26 ab	25 c
22	60 b	66 b	27 a	26 bc
33	55 b	62 b	27 a	27 a
44	42 b	51 b	26 ab	26 bc
66	52 b	61 b	27 a	27 a
C.V. (%)	20.5	24.2	2.7	2.6

Means in each column(s) with the same letter (s) are not significantly different according to Duncan's Multiple Range Test at 0.05 probability level.

The variety and planting density interaction effects on number of seeds per plant and 100- seed weight were significant in both seasons (Table 6). Hawata gave the highest number of seeds per plant at 17 plants/m^2 density and the heaviest 100- seed weight at the 66 plants/m^2 planting density, whereas those for variety FLIP-98-55C were comparable at all planting densities (Table 6).

Seed yield per plant and per hectare

Variety had significant effects on seed yield per plant in the second season only and highly significant effects on seed yield per ha in both seasons (Table 7). Hawata gave higher seed yield/plant than FLIP-98- 55C.These results supported the findings of Rubio *et al*. (2005) who reported that semi-erect chickpea cultivars gave higher seed yield per plant than erect ones.

Increasing planting density on the other hand, from 17 to 66 plants/m^2 significantly and consistently reduced the seed yield per plant in both seasons (Table 7). The reduction in seed yield/plant in chickpea due to increased planting density was reported by several workers including Opoku *et al*. (1996) and Gan *et al*, (2003). They stated that, as with other

Table 6. Interaction effects of variety and planting density on number of seeds per plant and 100-seed weight of chickpea grown at Hudeiba Research Station Farm in season 2009/10 and 2010/11.

Treatments	Number of seeds/plant		100- seed weight)g)	
	Season 2009/10			
	Variety			
Planting density (plants/m^2)	Hawata	FLIP-98-55C	Hawata	FLIP-98-55C
17	123 a	60 bc	21	31 bc
22	74 b	47 bc	21	32 ab
33	74 b	37 c	22	33 a
44	50 bc	35 c	22	31 bc
66	60 bc	43 c	22	31 bc
	Season 2010/11			
17	126 a	62 bcd	20 d	30 b
22	80 bc	51 cd	20 d	31 ab
33	82 b	41 d	21 d	33 a
44	60 bcd	42 d	21 d	31 ab
66	72 bcd	51 cd	23 c	31 ab

Means in each column(s) followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at 0.05 level.

legumes, chickpea seed yield/plant was higher at low planting density and attributed such a result to less competition of chickpea plants for nutrients and water.

On the other hand, the effects of the two varieties varied highly and significantly ($P \leq 0.001$) on seed yield in both seasons (Table 7). Hawata variety gave higher seed yield and exceeded FLIP- 98- 55C by 52 % in the first and by 110 % in the second season (Table 7). Similar results were reported by Rubio *et al. (*2005*)* who stated that seed yield was higher in semi- erect chickpea cultivars than erect ones. Also, in Sudan, Nouri (1986) found significant differences in seed and straw yields between a introduced (NEC-2486) and a local chickpea variety.

Planting density significantly ($P \leq 0.05$) affected chickpea seed yield in both seasons (Table 7). Increasing planting density from 17 to 33 plants/m^2 increased seed yield of chickpea but slightly decreased it with further increases in planting density to 44 and 66 plants/m^2, with the highest seed yield obtained at 33 plants/m^2 in both seasons. These results supported the findings of Regan *et al*. (2003). The reduction in chickpea seed yield as planting density was increased to 44 and 66 plants/m^2 agreed with Gan *et al*. (2003d) who reported that seed yield of chickpea was increased to a maximum with increased planting density from 20 to 45 plants/m^2 and then remained unchanged or decreased when planting density was increased to 50 plants/m^2.

The interaction effects of variety and planting density on seed yield per plant and seed yield per hectare of chickpea were significant in both seasons indicating that the two varieties responded differently to the planting densities used (Table 8). Seed yield of FLIP-98-55C was highest at 33 plants/m^2 in both seasons. As for Hawata seed yield did not significantly vary with planting density ranging from 22 to 66 plants/m^2. This result partially agreed with Saxena (1987) who found that tall up- right chickpea cultivars gave high seed yield at a plant density ranging from 25 to 30 plants/m^2.

Table 7. Main effects of variety and planting density on seed yield per plant and seed yield per hectare of chickpea grown at Hudeiba Research Station Farm during season 2009/10 and 2010/11.

Treatments	Seed yield/plant (g)		Seed yield /ha (kg)	
	Seasons			
	2009/10	2010/11	2009/10	2010/11
Variety				
Hawata	14	17	3310	3807
FLIP-98-55C	13	10	2165	1812
Planting density (plants/m^2)				
17	21 a	22 a	2409 b	2305 c
22	16 b	16 b	2592 ab	2435 c
33	12 bc	13 bc	3050 a	3429 a
44	10 c	10 c	2993 a	3289 ab
66	8 c	7 cd	2705 ab	2585 bc
C.V. (%)	17.8	18.8	12.3	15.8

Means in each column(s) with the same letter (s) are not significantly different according to Duncan's Multiple Range Test at 0.05 probability level.

Table 8. Interaction effect of variety and planting density on seed yield/plant and seed yield/ha of chickpea grown at Hudeiba Research Station Farm in season 2009/10 and 2010/011.

Treatments	Seed yield/plant (g)		Seed yield/ha (kg)	
	Season 2009/10			
	Variety			
Planting density (plants/m^2)	Hawata	FLIP-98-55C	Hawata	FLIP-98-55C
17	21 a	22 a	2779 bc	1909 d
22	18 a	14 b	3146 ab	2039 d
33	13 b	12 b	3448 a	2652 bc
44	9 c	11 bc	3726 a	2260 cd
66	9 c	7 cd	4346 a	1965 d
	Season 2010/11			
17	28 a	15 c	3901 ab	1553 ef
22	22 b	9 d	4371 a	1311 f
33	14 c	12 cd	3318 bc	2716 cd
44	10 cd	10 cd	3301 bc	1268 f
66	9 d	9 d	4143 a	2208 de

Means in each column(s) followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at 5 % level.

CONCLUSIONS

In conclusion, as the highest seed yields of chickpea (3050 and 3429 kg/ha) were obtained by the two varieties at 33 plants/m^2 planting density in both seasons, it was recommended that, to obtain high seed yield of chickpea in northern Sudan, the crop should be sown at 60 cm and 10 cm inter and intra- plant spacing, respectively, with two seeds/hole which is equivalent to a seed rate of 25 kg/fed.

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تأثير الصنف والكثافة النباتية في نمو وإنتاج الحمص المروي في ولاية نهر النيل- شمال السودان

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الخلاصة

يعتبر محصول الحمص من المحاصيل البقولية الأساسية وغذاء هام للإنسان والحيوان في السودان. عليه تم إجراء تجربة خلال موسمي 2009\10 –\2010\11 في محطة بحوث الحديبة التي تقع في شمال السودان في المناخ شبه الصحراوي. وذلك بغرض دراسة تأثير الصنف والكثافة النباتية في نمو وإنتاج الحمص المروي. استخدم الصنف حواته (شبه قائم) والصنف (فلب– FLIP-89 55C) قائم (مستجلب من المركز الدولي لبحوث المناطق الجافة (ICARDA) وزرع الصنفين باستخدام خمسة معاملات من الكثافة النباتية (17، 22، 33، 44 و66 نبات/ متر^2) والتي تعادل (170000، 0،220000، 330000، 440000 و660000 نبات/هكتار). أُستخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات. أوضحت النتائج تأثير عالي المعنوية للصنف ومعنوي للكثافة النباتية والتفاعل بين الصنف والكثافة في كلا الموسمين. الصنف حواتة مبكر في الإزهار بحوالي 17 و11 يوم في الموسم الأول والثاني علي التوالي بينما الصنف فلب تميز بالطول ب 17 و20 سم عن حواتة و10 و20 سم ارتفاع القرن الأول من سطح التربة عن حواتة. ومن ناحية أخري كان تأثير الكثافة النباتية ثابت ولكنه معنوي في 50% من عدد أيام الأزهار وطول النبات في الموسم الثاني فقط. أعطى الصنف حواته عدد أعلي من البذور للنبات في الموسمين وإنتاجية النبات الواحد في الموسم الثاني فقط عن الصنف فلب والذي تفوق عليه في وزن المائة حبة في كلا الموسمين. أوضحت النتائج أن عدد الحبوب بالنبات وإنتاجية النبات الواحد نقصت بزيادة الكثافة النباتية. كما أوضحت النتائج تفوق الصنف حواتة (3807 و3315 كجم/هكتار) عن الصنف فلب بسبة 53 و110 % في الموسم الأول والثاني علي التوالي، بينما زيادة الكثافة النباتية من 17 نبات إلي 33 نبات في المتر المربع أدي لزيادة معنوية في إنتاج بذور الحمص في كلا الموسمين (3429 و3050 كجم/هكتار). بلغت الإنتاجية أعلي قيمة لها في الكثافة النباتية 33 نبات في المتر المربع في كلا الموسمين وبذا نوصي بزراعة الحمص علي مسافة 60 و 10 سم في السراب والحفر علي التوالي أي ما يعادل 25 كجم بذور/ فدان.