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PLANT POPULATION DENSITY EFFECTS ON YIELD OF SORGHUM GROWN IN A DRY-LAND FARMING SYSTEM

By

A.M.A. ISMAIL* AND A.H. ALI**
*Department of Botany, Faculty of Science, University of Qatar, P.O. Box 2713, Doha, Qatar
**Crop Science Section, Ministry of Agriculture, Doha, Qatar.

تأثير الكثافة النباتية على إنتاج الذرة الرفيعة المنزرعة تحت نظام جاف

أحمد محمد على إسماعيل و أحمد حسن علي

إستهدفت الدراسة الكشف عن تأثير الكثافة النباتية على إنتاج الذرة الرفيعة من صنف «شحانية – ١» ، وذلك بتغيير عدد النباتات ونظام ترتيب النباتات على خطوط الزراعة . أظهرت النتائج أن زيادة الكثافة النباتية أدت إلى انخفاض معنوي في محصول الحبوب . كما أظهرت النتائج أيضاً أنه لم تكن هناك أية آثار مستحبة للمحصول عند تقريب المسافة بين النباتات على خطوط الزراعة إلى أدنى من ٢٠ سم . هذا وقد كانت الفروق في المحصول بين المعاملات المختلفة مقصورة على فروق في وزن الألف حبة ، وزن الرؤوس ، ومحصول الحبوب لكل نبات . أتت هذه النتائج مخالفة للمعروف عن أثر الكثافة النباتية على إنتاج الذرة الرفيعة في الدراسات السابقة . أمكنت النتائج من إصدار توصية بأنه للحصول على أعلى محصول للذرة الرفيعة يفضل أن تكون الكثافة النباتية في المدى ٨٣,٠٠٠ – ١٠٦,٠٠٠ نبات / هكتار وذلك في ظل نوعية الري والظروف المناخية السائدة في دولة قطر .

Key Words: Dry land farming system, Population density, Sorghum, Yield.

ABSTRACT

Plant population studies in arid regions are very sparse and not well documented. A prerequisite in growing a successful sorghum (*Sorghum bicolor* [L.] Moench) crop is to obtain an adequate plant population. The response of sorghum yield to plant population was examined in terms of both the number of plants per unit area and the arrangements of the plants on the row. Response of sorghum to factorial combinations of three intra-row spacings and two seeding rates was investigated from 1987 to 1989. The experiments were conducted on an alloctonus colluvial soil (calcareous sandy clay loam) in the Field Crop's Experimental Station, Rodat Horma, 25.0°N, Qatar under full irrigation conditions.The sorghum variety Sahania I was sown each year on 1 Sep and was harvested on 18 Jan. The experiments were set up in a split plot design with four replications. Yield depressions were recorded at high populations (166000 - 333000 plants ha^{-1}). The results show that an increase in plant density from a range of 53000 - 106000 to 166000 - 333000 plants ha^{-1} had contributed to the reduction in final grain yield. There is no benefit for yield from intra-row spacings closer than 20 cm. Most of the yield differences were associated with differences in 1000-grain weight, head weight and grain yield per plant. These results contrast with responses to increasing population recorded in most previous studies and indicate that clear optimal plant ranges must be defined. When planting sorghum for higher yields under irrigation under Qatari conditions an optimal plant population of 83000 - 106000 plants per ha is desired.

* Corresponding author

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is an important food grain and fodder crop throughout much of the tropics and subtropics of the Americas, Africa, Asia and Australia. In tropical regions it is grown largely as a rainfed crop during the fall season, or in residual soil moisture after river floods. Both situations may be characterized by periods of water shortage which may limit productivity. Qatar and other Arabian Gulf states have a climate that allows two cropping seasons per year. For example, the climate of Qatar is characterized by scanty rainfall during the winter season, high temperatures and hot dry winds during the summer and high relative humidity for the greater part of the year. The choice of traditional winter crops under irrigation is limited to wheat (*Triticum aestivum L.*), maize (*Zea mays L.*) and barley (*Hordeum vulgare L.*) as forages and grain crops. Sorghum has the potential to fill the void of summer grown crops thus spreading the farm workload at both planting and harvest time.

The response of sorghum to plant population density has been investigated in many areas of the world [1-11] but most studies have been in subtropical areas of the United States and Australia. Detailed population studies [10] carried out in Queensland (Australia) under irrigation showed that high populations of sorghum (4 and 8 x 10^5 plants ha^{-1}) were always superior or equal to the standard population (2 x 10^5 plants ha^{-1}) in grain yield. Other authors [6] reported that no significant differences in yield were detected among five different populations ranging from 40000 to 120000 sorghum plants; [11] have also recorded increased grain yield for sorghum with increased plant density. No information is available on the effects of population density on sorghum yield components and final grain yield in the Gulf region e.g. Qatar, particularly in the absence of moisture stress.

In addition to the question of population density the optimal planting geometry for sorghum in irrigated farms is unsettled. [5] indicated that double-row (two 10- or 12-inch rows) sorghum increased grain sorghum yield over single 40-inch rows. [12] found no detectable differences in yield in grain sorghum whether it was planted on 20-inch single row or 40-inch double-row spacing. [6] found little difference in the effects of row width on yields, but double rows on 40-inch beds appeared to be the easiest to irrigate and produced near maximum yields. No reports of within-row plant spacing on sorghum yield components and grain yield have been reported in Qatar.

Continuing to expand on earlier studies [13] an experiment was undertaken during the two successive seasons of 1987/1988 and 1988/89 (1 Sep to 18 Jan) in Qatar under irrigation conditions to examine the grain yield and yield components in the sorghum variety Sahania I (a high yielding variety under Qatari conditions) in response to plant population. The response was examined in terms of both the number of plants per unit area (plant density) and the arrangements of the plants on the row (intra-row spacing).

MATERIALS AND METHODS

The experiments were conducted at the Field Crops Experimental Station, Rodat Harma, very near to Doha capital of the State of Qatar (50°45' - 51° 40' E and 24° 46' - 26° 10' N) during the two consecutive sorghum cropping seasons of 1987/88 and 1988/89 as from 1 Sep to 18 Jan. The meteorlogical data during the course of these experiments are presented in Table 1.

The soil type at the experimental site is known locally as 'Rodat Soil' and is derived from colluvial deposits which are accumulated by run-off carrying weathering products from surface rocks of neighbouring products i.e. alloctonus type of soil. These soils are described as calcaerous sandy clay loam ($CaCO_3$= 34 - 60%, EC = 0.77 - 6.99 dS/m, organic matter = 0.78%, pH = 7.0 - 8.4; cations are: Ca, Mg, Na, K; anions are: sulphate, chloride and bicarbonate).

The recommended high yielding variety Sahania I was planted on rows, 5 m in length and a constant row width of 60 cm at a range of populations and planting patterns. Population density changes were within rows. A row within a subplot was thinned by hand to the desired plant population of 50 (10 cm space), 25 (20 cm space) and 16 (30 cm space) plants per 5 m row when leaving one plant $hill^{-1}$, or 100, 50 and 32 plants when leaving two plants $hill^{-1}$ (Table 2), 21 days after emergence. The experiment was arranged in both growing seasons in randomized complete block design with a split plot arrangement with four replicates. Plant spacings were assigned to main plots and the number of plants per hill to the subplots.

Arable cropping in Qatar is totally dependent on irrigation as rainfall is erratic, scanty and confined to winter months (Dec - Feb). Therefore the crop was full irrigated, and nineteen postplanting irrigations were applied each season. Irrigation water was pumped from wells. The amounts of water which were applied at each irrigation were not fixed values but depended on the soil temperature, air temperature and the rate of evapotranspiration. Plots were never stressed for moisture. No water was given after the crop has reached the dough stage. Phosphorus fertilizer (16%) was applied at a rate of 60 kg ha^{-1} after the seedling's stage. Nitrogen fertilizer was applied at a rate of 150 kg ha^{-1} in the form of urea (46% N) splitted in two applications during the growing season, three weeks after planting and before bloom-ing. Hand hoeing controlled the emerging weeds in both seasons. The main plot area was 24 m^2, all data were taken from the two inner rows for every subplot with a total area of 6 m^2. Variables measured included one thousand grain weight (g), head weight (g), grain yield per plant (estimated from counts and weights of 1 m section of each harvested inner row in each subplot) and grain yield was based on the weight of the threshed sample from the harvested section of the plot (6 m^2) and converted to ton ha^{-1} at 12-13% moisture.

Data were analysed by analysis of variance for each growing season. Means were compared using LSD test.

Table 1
Monthly summaries of growing season climatic data

Month	Temperature			Relative humidity			Rainfall
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	
		°C			%		mm
			1987/1988				
August 87	42.4	28.2	35.3	96.1	20.4	58.3	00.00
September	41.4	25.2	33.3	96.6	14.7	55.7	00.00
October	35.9	21.9	28.9	97.5	23.2	60.4	03.20
November	30.1	16.9	23.5	99.2	28.7	64.0	00.00
December	24.9	13.9	19.4	88.6	32.5	60.6	00.00
January 88	21.4	11.0	16.2	86.6	34.6	60.6	18.20
February	22.5	13.5	18.0	86.6	42.1	64.4	134.40
Mean	31.2	18.7	24.9	93.0	28.0	60.6	22.00
August 88	43.6	27.4	35.5	90.4	12.0	51.2	00.00
September	41.9	25.7	33.8	91.4	16.7	54.1	00.00
October	37.7	20.9	29.3	92.3	10.1	51.2	00.00
November	29.6	16.5	23.1	90.2	24.7	57.5	00.00
December	25.0	12.8	18.9	92.7	29.2	61.0	00.00
January 89	18.9	7.5	13.2	90.2	24.8	57.5	00.00
February	21.5	9.2	15.4	91.4	18.1	54.8	04.00
Mean	31.2	17.1	24.2	91.2	19.4	55.3	00.62

Table 2
Treatment populations and patterns.

Plant spacing within a row	Number of plants per row		Number of plants per ha	
Cm	1 plant per hill	2 plants per hill	1 plant per hill	2 plants per hill
10	50	100	166000	333000
20	25	50	83000	166000
30	16	32	53000	106000

RESULTS AND DISCUSSION

Environment

Weather was characterized by large day and night temperature differentials as is common in arid regions. The two growing seasons of 1987/88 and 1988/89 were similar climatically. Nevertheless the rainfall which occurred in Feb of 1988 has no irrigation value to the crop as the crop had already been harvested during Jan of 1988 (Table 1).

Effect of Plant Spacing

As plant spacing was increased from 10 cm (166000 - 333000 plants ha^{-1}) to 30 cm (53000 - 106000 plants ha^{-1}) between hills within a row there was a significant increase in 1000-grain weight, head weight, grain yield $plant^{-1}$ and final grain yield (ha^{-1}). The percentage increase in yield components and grain yield were 6, 71, 72 and 10% for season 1987/88 and 3, 80, 83 and 26% for season 1988/89 for the 1000-grain weight, head weight, yield and final grain yield (ha^{-1}), respectively (Table 3).

No significant differences were observed for the same four yield components between plants grown at 20 cm spacing (83000 - 166000) and those planted at 30 cm spacing between hills within a row in both growing seasons.

These results show that the increase in plant density from the

Table 3
Effect of plant population density on grain yield and its components.

Plant spacing	1987 / 1988 1000-grain weight	Head weight	Yield plant^{-1}	Grain yield	1988 / 1989 1000-grain weight	Head weight	Yield plant^{-1}	Grain yield
- cm -	- g -	- g -	- g -	- Ton ha^{-1}	- g -	- g -	- g -	- Ton ha^{-1}
10	36	57	32	3,78	40	55	36	5.02
20	38	89	54	4.17	41	86	56	6.04
30	38	98	55	4.88	41	99	66	6.60
Significance	**	**	**	**	*	*	**	*
LSD (0.05)	20	9	6	0.47	1	13	11	0.89

* Significant at 0.05 probability level
** Significant at 0.01 probability level

Table 4
Effect of number of plants on grain yield and its components.

Number of plants hill^{-1}	1987 / 1988 1000-grain weight	Head weight	Yield plant^{-1}	Grain yield	1988 / 1989 1000-grain weight	Head weight weight	Yield plant^{-1}	Grain yield
	- g -	- g -	- g -	- Ton per ha -	- g -	- g -	- g -	- Ton per ha -
One	38	95	56	4.64	41	87	58	6.83
Two	37	68	38	3.92	40	73	47	6.08
Significance	**	**	**	**	*	*	*	*
LSD (0.05)	1	6	5	0.54	1	11	9	0.29

range 53000 - 106000 plants per ha (30 cm spacing) to the range of 166000 - 333000 plants per ha (10 cm spacing) contributed to the reduction observed in the measured yield components and final grain yield of sorghum. These results are consistent with those of [14] who indicated that intraspecific competition (proximity to neighbours) can modify plant growth and reproduction by reducing the size of the survivors which in turn reduces the seed output.

Effect of Plant Number per Hill

Significant depressions in grain yield and its components at high populations (2 plants/hill) were detected compared to the low population (1 plant/hill). The percentage reduction in grain yield and its components were 3, 29, 32, 11% in 1987/88 growing season, and 3, 17, 19 and 11% in 1988/89 growing season for 1000-grain weight, head weight, yield and final grain yield, respectively (Table 4). These results with sorghum agree with those of [7] who showed that additional sorghum at post-floral initiation resulted in large decreases in grain number and weight, and contrast markedly with those of [11] who indicated that sorghum yield increased with increasing population. [12] argued that plant population in sorghum is more important than row spacing *per se* in determining yield. [15-16] indicated that the response of grain yield to increasing plant population is likely to be unique for each genotype in its environment.

Effect of Interaction between Plant Spacings and Number of Plants per Hill

In 1987/88 and 1988/89 growing seasons the 1000-grain weight was similar in relation to plant spacings and number of plants . In neither growing season in which this characteristic was measured did a plant spacing-by-number of plants per hill interaction occurred.

Generally head weight increased as the plants - one or two per hill were distantly spaced. For example the head weight was 63-67 g with one plant per hill at a spacing of 10 cm,but was 99-113 g at a spacing of 30 cm in both growing seasons. A spacing-by-number of plants per hill interaction did not occur in either season.

Grain yield and final grain yield increased in both growing seasons as plant spacing - irrespective of number of plants per hill - were distantly spaced. The 20 and 30-cm spaced plants had similar but higher grain yield per plant and also similar but higher final grain yield compared to the narrow spacing of 10-cm. No significant plant spacing-by-number of plants per hill interaction was observed in both growing seasons of 1987/88 and 1988/89.

That no significant differences between plant spacing and number of plants per hill for the four components (yield and its components) measured, were detected, indicate no environmental influences. It is interesting to note that sorghum plant population had no consistent effect on sorghum yield components. This result is in agreement with the finding of M'Khaitir and Vanderlip [11] for sorghum. At low populations sorghum plants produce more and larger heads than at high population stands. In the present investigation sorghum plants produced larger heads at lower populations with increasing intra-row spacing than at higher populations with decreasing intra-row spacing. Apparently, the plants were mutually shaded at high populations and tended to elongate thus creating a greater competition for photoassimilates between the growing head and the elongating stem. This results in smaller heads forming on the main stem which in turn results in less grain yield per plant and thereafter less final grain yield per ha.

CONCLUSIONS

Plant spacing and plant density had consistent effect on yield of sorghum. These responses emphasize the importance of intraspecific competition in the expression of yield components of sorghum. Planting sorghum under irrigation conditions to attain a final plant population of 83000 - 106000 should be the goal when planting for the highest yields under dry-land farming.

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