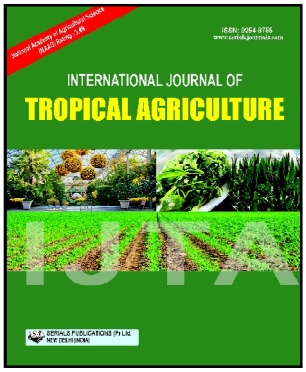

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Crop and Varietal Diversification of Integrated Cropping Systems in Maize and Okra for Higher Productivity and Profitability

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Abstract: The availability of land for agriculture is shrinking every day as it is increasingly utilized for non-agricultural purposes. World population is growing exponentially and it has to fulfill their food requirements. Under this situation, one of the important strategies to increase agricultural output is the development of new high intensity cropping systems including intercropping systems.Keeping this view in mind, field experiments were conducted at Indian Agriculture Research Institute, New Delhi, to evaluate the physiological and yield response of three maize variety and okra under intercrop in contrasting water regimes with different planting system. The water regimes affecting the three cropping systems (sole maize, sole okra and the intercrop of okra and maize) constituted the treatments, which were laid out in a ridge and furrow planting system. Physiological parameters such as SPAD chlorophyll content, relative water content (RWC), water potential, photosynthesis rate, stomatal conductance and leaf temperature have been recorded in Maize and Okra crop under irrigated (IRR) and life saving(LS) treatment. Higher RWC 85.45% was observed in Maize grown on ridge than Maize grown on furrow 83.24%. SPAD value was higher in Okra than maize under IRRand LStreatment. Leaf transpiration value was higher in Maize than Okra in ridge sowingunder LS and IRR condition. Grain yield was higher in IRR than LS condition. Variety Bio6937 showed higher yield in LS treatment.

Keywords: Cropping system, grain yield, diversification, maize, okra

INTRODUCTION

The importance of cereal grains in human nutrition is widely recognized, as they provide substantial amounts of energy and protein to millions people, especially in developing countries (Shewry 2015). Intercropping is a common cropping system in developing countries such as India. It is the practice of growing two or more crops at the same time during the same growing season on the same piece of land. With the rapid population increase, the demand for food has been increasing while land availability has been declining. Thus, the only way to increase agricultural production is to increase yield per unit area (Seran and Brintha 2010). This cropping system increased total productivity per unit land, per unit time and improves the judicious utilization of the land and other resources on farm.

Maize (Zea mays L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. Maize is cultivated throughout the world (58°N latitude to 40°S latitude) in an area of 179.9 m.ha across 165 countries with a production of 1013.6 m.t and average productivity of 5.63 t/ha. India occupies 7th position in respect of area and production. Maize is used mainly for human food and livestock feed while in the industry, it is also very important as it is used in the production of starch, oil and alcohol (Godfrey *et al*. 2010). Okra (Abelmoschusesculentus L. Moench) is one of the priority vegetable crops in India (Das *et al*. 2012). It is a nutritious vegetable, rich in vitamins, calcium, potassium and other minerals (Poggio, 2005). Intercropping generally not only minimizes risks due to crop failure under adverse environmental conditions but also gives a higher total return per unit area of land (Ijoyah and Jimba, 2011).

Maize and okra planted as soles are sensitive to low temperature and develops poorly below 15 °C (Sanghamitra, 2006). Studies on the optimum weather requirement for high yields from mono-cropped maize and okra under rainfed conditions showed that the crops perform best when the minimum and maximum temperatures are respectively between 18 °C and 35 °C (Ezeakunne, 2004). Katung (2007) reported that monocropped okra under rainfed conditions require high temperature of about 28 °C and long day length for optimum growth and development. He also reported an improvement in the performance of okra when rainfall was about 750 mm, evenly distributed with relative humidity between 80-85%. These studies have dwelt extensively on the optimal weather requirements for the crops when planted as soles under rainfed conditions. Plants under water deficit stress exhibit a number of morpho-physiological and biochemical response. Photosynthetic rate is among the most common physiological response and this changed due to closure of stomata and/ or inhibition in the activity of enzyme involved in photosynthesis. Determination of water relation components at the whole plant or cellular level is important for determination of resistance of species or cultivar to drought stress. However, there is a dearth of information on the yield response of maize and okra, either planted as soles or in intercrop under different seasonal conditions. Thus the major objective of the present study was to uncover the crop response to water deficit stress by evaluating the physiological and yield parameters under various cropping system and different water regimes.

MATERIALS AND METHODS

The experiment was conducted in years 2015 and 2016 at Indian Agriculture Research Institute, New Delhito evaluate the physiological and yield response of intercropped maize and okra to seasonal conditions. Field trials were conducted at Water Technology Centre, I.A.R.I, New Delhi ((77°12'E, 28°40'N; 228.6 M.S.L), The average monthly rainfall, temperature, relative humidity and mean daily solar radiationswere recorded throughout the seasons. The variety of maize was PEMH-5, HQPM-1, Bio-6937 and okra.Both varieties are popular varieties grown by farmers and shows good adaptation to the local environment.

The experimental area which consisted of sandy-loam soil was ploughed, harrowed, ridged and divided into 12 plots. Each plot had an area of 12

m^2. The plot consisted of 4 ridges in which 10 okra plants per ridge were planted at a spacing of 100 cm x 30 cm, giving a total plant population of 40 okra plants per plot. Okra seeds were planted about 2-3 cm deep in a single row on top of the ridges. Three maize seeds were planted per position, which were later thinned to one plant per position at 5 days after planting (DAP). The cropping systems (sole maize, sole okra and the intercrop of okra and maize) constituted the treatments, laid out in a randomized complete block design (RCBD) with four replications. The recommended rate of compound fertilizer NPK 100 kg N ha-1, 40 kg P ha-1 and 60 kg K ha-1 were applied (Purakayastha *et al*., 2008). The row method of fertilizer application was employed. The fertilizer was applied twice to each plot at 3 and 6 weeks after planting for the sole crops and the intercrops. Weeding was done using the native hoe as the need arose. The use of native hoe is a typical practice by farmers in the area. Okra was harvested when the tip of pod was observed to break easily when pressed with the finger tip. Maize was harvested at 12 weeks after planting (WAP), when the leaves turned yellowish and fallen off which were signs of senescence and cob maturity. The entire plots were harvested for yield measurements.

Physiological parameters such as SPAD chlorophyll content, relative water content, water potential, photosynthesis rate, stomatal conductance and leaf temperature have been recorded. Photosynthetic rate (PN) was measured between 09:00 and 10:00 h local time at vegetative (30-33DAE), flowering (45-48 DAE) and grain filling (60-63DAE) with the help of portable photosynthesis system (Model LI: 6400, LICOR, Lincoln, NE, USA). Measurements on PN, stomatal conductance (gs), transpiration (E) and leaf temperature were recorded in three selected plants of each variety and replicate on the leaf situated just below the cob at the natural leaf angles facing sun in the canopy. The measurements were performed on three consecutive days and three observations on single leaf of three different plants of each hybrid were recorded on each day.Total chlorophyll content was estimated by SPAD index (leaf greenness) measured with a chlorophyllometer (SPAD-502, Minolta, Osaka, Japan).

Relative water content (RWC) were measured at flag leaves at post-anthesis stage (A+14) under both IRR and LS treatments following the procedure given by Barrs and Weatherly (1962). Pressure bomb apparatus was used to determine the leaf water potential of the plants. The apparatus was shifted to field for the measurements. Leaf was excised along with the petiole and inserted in the pressure chamber. The gas was turned on and tip of petiole was carefully observed with the help of lens to observe for a drop of moisture. The gas was immediately turned off after the observation of moisture drop on leaf petiole. The reading was taken on the screen and converted into Mega Pascal (MPa). Plants were sampled for the measurement of grain yield and biomass in 1 m^{-2}area in each replicate and hybrid, after thorough drying in sunlight plant samples were weighted.

STATISTICAL ANALYSIS

All data were statistically treated using the Analysis of variance (ANOVA) for randomized complete block design and the Least Significant Difference (LSD) was used for mean separation ($P \leq 0.05$) following the procedure of Steel and Torrie (1980).

RESULTS AND DISCUSSION

Significant stress in terms of water potential was observed in flowering and post flowering stage of the crop in all the treatments under LS condition. Higher water potential was observed in Okra than Maize variety under LS treatment. Consumptive use and rate of moisture use were higher in the intercropping system than sole crop because both the crops absorbed more moisture during the crop period. RWC have been reported to be associated with drought tolerance (Blum, 2005). Variety Bio-6937 showed higher RWC as compared to other variety.Maize and Okra grown in ridge planting showed higher RWC than furrow planting.Favorable expression of water relation traits are indicators of the capacity of the crop to access water from deeper layers of soil under water stress condition as a result of deep and dense root system (Reynolds *et al.*, 2005; Blum *et al.*, 1989). Deep root system increases the total water availability to the crop under water stress condition and is associated with improved drought tolerance (Reynolds *et al.*, 2007). SPAD Chlorophyll was measured at vegetative, flowering and post flowering stages of the crop maize and Okra under LS andIRR treatment.SPAD Chlorophyll value was higher in maize than Okra under LS and IRR treatment.Higher photosynthesis was observed in flowering stage followed by vegetative and post flowering stage of the crop under irrigated and LStreatment.Photosynthesis value was higher in Maize than Okra under LS and IRR treatment.Variety Bio-6937 showed higher photosynthetic related traits and higher RWC as compared to other variety.

Yield response of maizeplanted as sole and in intercrop with okra to different planting conditions is given in Fig. 1. Generally, greater yield of okra was obtained under the IRR condition than in the LS condition (Fig. 1). The reduction in seed yield by intercropping could be due to interspecific competition and depressive effect of maize, a C4 species on OKra, a C3 crop. Crops with C4 photosynthetic pathways such as maize have been known to be dominant when intercropped with C3 crops like Okra. The reduction in intercropped Okra could be due to shading by the taller maize plants. Muoneke *et al.*, (2007) reported that shading by the taller plants in mixture could reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields.Compared with corresponding sole crop yield advantages have been recorded in intercropping crops also grain yield was higher in ridge planting as compared to furrow planting.A cropping systems approach may offer opportunities for producers to increase economic returns. Management of dynamic cropping systems will need to be based not only on single-year profit opportunities, but also on subsequent crop sequence effects. Thus, to more productivity and market rates of the mixed crops and low cost of cultivation also helped in increasing yield and economics returns which ultimately effects on system productivity and profitability.

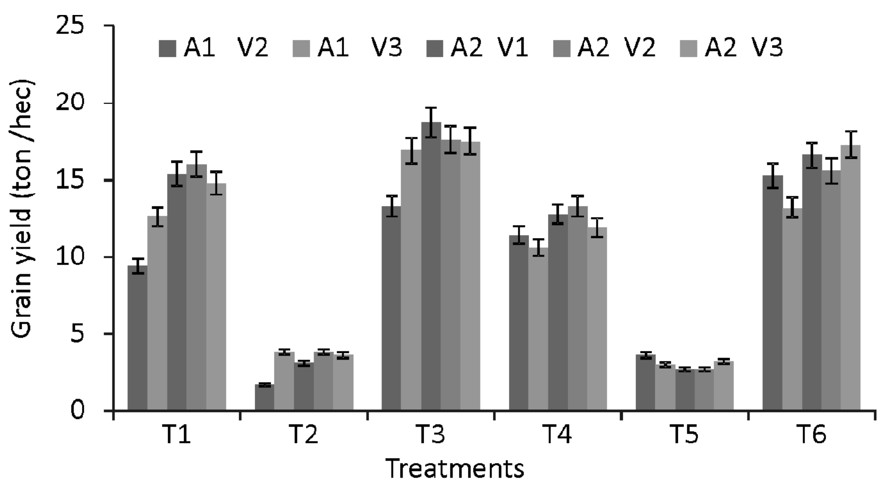

Figure 1: Mean grain yield under different treatments

(T1: Sole Maize+ Ridge Planting, T2:Sole Okra + Ridge Planting, T3:Maize+ Okra + Ridge planting, T4:Sole Maize + Furrow Planting , T5:Sole Okra + Furrow Planting, T6:Maize + Okra + Furrow Planting, A1 = life Saving irrigation, A2= Irrigated)

Table 1
Relative water content (%) in Maize and Okra variety under life saving (LS) and Irrigated (IRR) treatments at three different stages of the crop under different treatment

Stage		*Vegetative*		*Flowering*		*Post Flowering*	
Variety	*Treatment*	*LS*	*IRR*	*LS*	*IRR*	*LS*	*IRR*
PEMH-5	T1	85.45	88.23	77.77	80.23	65.87	71.76
	T2	83.24	88.67	78.04	81.54	66.43	75.06
	T3	83.65	84.44	79.95	80.34	62.87	75.00
	T4	83.52	84.81	78.57	79.43	65.46	71.76
	T5	80.25	83.56	77.85	81.26	68.86	72.60
	T6	82.54	85.81	76.00	77.45	65.98	73.76
HQPM-1	T1	82.75	84.65	76.76	78.52	74.16	76.14
	T2	83.63	84.35	80.00	78.54	68.49	72.65
	T3	80.65	82.76	75.44	77.65	68.41	71.73
	T4	82.58	83.76	77.32	79.87	69.81	70.65
	T5	80.15	83.26	76.00	77.54	69.97	73.87
	T6	81.54	84.76	75.61	78.53	66.67	73.72
Bio-6937	T1	86.64	89.23	78.53	82.87	69.65	78.54
	T2	85.34	89.76	79.15	81.54	68.22	74.67
	T3	86.83	88.65	79.32	80.54	72.51	75.28
	T4	83.54	84.76	77.23	79.76	70.53	73.83
	T5	82.65	85.76	78.38	79.48	71.21	73.82
	T6	82.76	83.76	76.56	78.87	73.59	75.65
CD at 5%		0.42	0.75	0.52	0.61	0.34	0.51

Table 2
Water potential in Maize and Okra variety under life saving (LS) and Irrigated (IRR) treatments at three different stages of the crop under different treatment

		Vegetative		*Flowering*		*Post Flowering*	
Variety	*Treatment*	*LS*	*IRR*	*LS*	*IRR*	*LS*	*IRR*
PEMH-5	T1	-7.4	-6.9	-10.3	-9.8	-17.0	-14.7
	T2	-8.2	-7.2	-11.2	-9.0	-16.3	-14.2
	T3	-8.0	-7.8	-10.8	-9.3	-19.2	-13.9
	T4	-7.9	-7.3	-10.5	-9.2	-18.2	-14.2
	T5	-7.5	-7.0	-11.0	-8.9	-16.9	-13.2
	T6	-7.8	-6.8	-11.3	-9.6	-16.1	-15.1
HQPM-1	T1	-8.9	-7.4	-9.8	-8.5	-18.2	-15.3
	T2	-8.7	-7.1	-10.4	-9.4	-19.2	-13.0
	T3	-8.5	-7.6	-10.2	-9.0	-17.3	-13.2
	T4	-9.0	-7.9	-10.8	-9.8	-16.8	-14.6
	T5	-8.4	-7.2	-11.8	-10.0	-15.9	-15.0
	T6	-8.6	-7.4	-11.3	-9.5	-18.2	-14.2
Bio-6937	T1	-8.2	-7.1	-10.8	-9.4	-17.3	-14.2
	T2	-8.4	-7.8	-10.9	-9.0	-17.9	-13.2
	T3	-8.2	-7.4	-10.3	-9.3	-18.9	-14.1
	T4	-8.0	-7.9	-10.2	-10.4	-18.3	-13.8
	T5	-8.1	-7.3	-10.8	-10.2	-18.0	-13.2
	T6	-8.5	-7.9	-10.9	-9.0	-17.2	-12.6
CD at 5%		-0.16	-0.22	-0.12	-0.17	-0.13	-0.29

Table 3
SPAD Chlorophyll Value in Maize and Okra variety under life saving (LS) and Irrigated (IRR) treatments at three different stages of the crop under different treatments

Stage		*Vegetative*		*Flowering*		*Post Flowering*	
Variety	*Treatment*	*LS*	*IRR*	*LS*	*IRR*	*LS*	*IRR*
PEMH-5	T1	57.4	58.4	50.5	52.2	33.5	39.1
	T2	54.7	59.7	51.7	53.2	35.2	40.7
	T3	57.0	60.0	50.3	51.3	31.4	35.8
	T4	56.6	59.6	49.6	50.1	30.2	33.6
	T5	58.5	61.5	51.5	57.5	31.5	33.7
	T6	60.1	63.5	54.3	58.1	27.8	30.5
HQPM-1	T1	57.1	59.1	52.5	53.2	36.4	42.7
	T2	55.8	58.5	51.4	56.5	32.5	36.3
	T3	63.6	64.6	54.6	55.1	30.1	32.7
	T4	61.4	62.5	53.2	54.5	31.3	35.8
	T5	58.7	59.3	51.3	52.5	30.4	33.6
	T6	56.5	58.4	50.3	51.4	32.1	37.4
Bio-6937	T1	58.1	59.7	52.5	53.3	30.3	36.3
	T2	57.4	58.5	50.7	51.8	29.6	32.7
	T3	55.1	56.9	51.5	52.0	32.5	32.5
	T4	54.6	58.7	48.9	49.2	30.6	33.7
	T5	55.8	57.6	50.1	51.5	28.9	32.6
	T6	57.4	58.4	52.5	53.3	29.1	32.3
CD at 5%		1.4	1.7	1.9	1.5	1.1	1.2

Table 4
Photosynthesis rate (μmol $m^{-2}sec^{-1}$) in Maize and Okra variety under life saving (LS) and Irrigated (IRR) treatments at three different stages of the crop

Photosynthesis		*Vegetative*		*Flowering*		*Post flowering*	
Variety	*treatment*	*IRR*	*LS*	*IRR*	*LS*	*IRR*	*LS*
PEMH-5	T1	20.31	18.75	27.86	25.78	10.01	9.12
	T2	18.63	14.56	28.72	24.04	8.53	7.63
	T3	18.97	16.66	28.29	25.91	9.27	8.37
	T4	17.51	15.50	27.50	25.36	8.75	7.86
	T5	14.86	12.85	20.22	18.09	8.02	7.12
	T6	16.18	14.17	23.86	21.73	8.39	7.49
HQPM-1	T1	22.01	20.11	24.79	20.94	1.7	1.1
	T2	17.61	15.60	24.66	20.50	9.41	8.51
	T3	21.03	19.35	24.72	21.22	11.00	10.10
	T4	22.64	20.63	32.84	30.71	12.73	11.84
	T5	15.04	13.03	18.11	15.98	7.98	7.08
	T6	18.84	16.83	25.47	23.34	10.36	9.46
Bio-6937	T1	23.68	21.67	30.79	28.42	10.73	9.83
	T2	16.86	14.85	18.23	20.80	8.63	7.73
	T3	20.23	19.26	24.51	20.61	9.68	8.78
	T4	18.75	16.58	23.98	21.84	9.55	8.65
	T5	16.52	14.51	18.50	16.37	8.63	7.74
	T6	17.93	16.55	21.24	19.11	9.09	8.20
CD at 5%		1.5	2.1	1.4	1.3		

CONCLUSION

From the results obtained, it can be concluded that it is more advantageous to intercrop maize and okra under the IRR condition compared to intercropping under LS condition. This is associated with a greater total intercrop yield, higher land equivalent ratio and greater percentage of land saved. It is, however, recommended that further investigation be evaluated across a wider combination of Okra and Maize varieties.

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