GROWTH, YIELD, WATER USE EFFICIENCY AND COMPETITIVE FUNCTIONS OF INTERCROPPING SYSTEM OF MAIZE (*Zea mays* L.) AND MUNGBEAN (*Vigna radiata* L.) AS INFLUENCED BY IRRIGATION

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ABSTRACT

Field experiment was conducted at Instructional Farm, Jaguli (Mohanpur), Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India during two consecutive summer seasons of 2010-11, and 2011-12. The experiment was laid out in split-plot design having 4 levels of irrigation– rainfed without mulch, rainfed with mulch, irrigation at IW (depth of irrigation water) / CPE (Cumulative pan evaporation) ratios of 0.5 and 0.75 in main-plot and 4 inter cropping systems, sole maize, sole mungbean, maize + mungbean (1:1 row ratio) and maize + mungbean (3:2 row ratio) considered as sub-plot treatments replicated thrice. Results revealed that application of irrigation and intercropping systems markedly influenced the growth, yield and yield components (number of cobs/plant, number of grains/cob in case of maize and number of pods/plant and number of seeds/pod in case of mungbean) where the maximum value of these components were recorded with the application of irrigation at IW/CPE ratio 0.75 in sole crop. Maize-mungbean in 3:2 row ratio yielded higher than that of 1:1 intercropping system which might be due to less light interception and more competition for water and nutrition between both the crops. CU of water increased with the increasing levels of irrigation and the maximum value (17.75 kg ha^{-1} mm^{-1}) of WUE (water use efficiency) was observed with irrigation at IW: CPE ratio 0.75 under intercropping system of maize : mungbean in 3:2 row ratio followed by IW: CPE ratio 0.50. Among the sole crop, maximum WUE was with IW/CPE ratio 0.75 might be due to more consumption of water corresponding to production potential of maize, while, it was more under rainfed with mulch in mungbean. The relative crowding coefficient (RCC) also revealed both the intercropping systems were advantageous and the land equivalent ratio (LER) increased with the level of irrigation.

Thus, maize grown in association with mungbean (3:2 row ratio) were found to be more profitable (B:C ratio of 2.58) with higher monetary advantage as compared to sole crop of maize (B:C ratio of 1.98) with the application of irrigation at IW: CPE ratio of 0.75 in new alluvial zone of West Bengal.

Keywords: Intercropping system, maize-mungbean, irrigation, growth,

yield, water use efficiency, competitive functions

INTRODUCTION

Intercropping is considered the best means of stabilizing yield, crop production by increasing the productivity of land and also minimizing the risk of crop failure in dry lands. Many instances of better insect-pest and disease control have also been reported by Mandal et al. (1990) and Banik and Sharma (2009) through intercropping system. In India, agriculture is mainly based on monsoon that is mostly uncertain and unevenly distributed over the sub-continent. So, in such situation, proper scheduling of irrigation maintains the soil moisture at levels up to the crop needs. Maize (*Zea mays* L.) is one of the most important cereals after rice and wheat that shows great adaptability to wide range of agro-climatic regions and soil types. Among the pulse crops, mungbean (*Vigna radiata* L.) being leguminous, short duration pre-*kharif* crop with high quality protein (nearly 25%) could be well fitted in various intercropping systems. In view of the above context, this experiment was undertaken with the objectives to study the growth, yield and water use efficiency of maize and mungbean grown as sole and intercrop as influenced by levels of irrigation in this agro-zone.

MATERIALS AND METHODS

The experiment was conducted during two consecutive pre-*kharif* or summer seasons of 2010-11 and 2011-12 at Instructional Farm, Jaguli (Mohanpur), Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India in upland situation. The soil of the region was nearly neutral with pH of 6.45 and sandy loam in texture. Physico-chemical properties of the experimental soil up to the depth of 15 cm were studied to know the initial status before conducting the experiment (Table 1). The soil of experimental field was sandy loam in texture with moderate drainage facilities having medium fertility status and neutral in reaction (pH 6.45). The important characteristics were medium organic matter and total nitrogen content of 0.059%. The values of available P and K were determined 8.71 kg and 104.9 kg ha^{-1}, respectively. Besides, bulk densities values of soil at depths (0-15) cm, (15-30) cm, (30-45) cm and (45-60) cm were measured 1.45, 1.47, 1.49 and 1.52 g cc^{-1}, respectively.

Cultivars of maize and mungbean used were 'Deccan 105' and 'Sonali', respectively. Field experiment was carried out under irrigated conditions laid out in

split-plot design with 4 levels of irrigation (main-plot treatments) and 4 cropping systems (sub-plot treatments) replicated thrice. Total number of plots was 48 each of 20 sq m area (5 m x 4 m) and irrigation channel was provided of 1.0 m width including 1.0 m of buffer channel in between main-plot irrigation treatments avoiding any water transfer by seepage among the adjacent plots.

In main-plot treatments, the levels of irrigation were as follows: I_0 = rainfed without mulch, I_1 = rainfed with mulch, I_2 = irrigation at IW/CPE ratio of 0.5 and I_3 = irrigation at IW/CPE ratio of 0.75 and 4 different intercropping systems under sub-plots were: C_1 - sole maize, C_2 - sole mungbean, C_3 - maize: mungbean maintained at 1:1 row ratio and C_4 - maize: mungbean maintained at 3: 2 row ratio, respectively.

Growth parameters such as plant height (cm), crop growth rate (CGR, g m^{-2} day^{-1}), dry matter accumulation (g m^{-2}), leaf area indices (LAI) were recorded. Besides, yield and yield components viz., number of cobs $plant^{-1}$, length of cobs, number of grains cob^{-1}, test weight and grain yield (t ha^{-1}) in case of maize; number of pods $plant^{-1}$, length of pods, number of seeds pod^{-1}, test weight and seed yield (t ha^{-1}) in case of mungbean were also recorded Furthermore, consumptive use of water (mm), water use efficiency (kg ha^{-1} mm^{-1}) was also analysed using the following equations:

$$U \;=\; \sum u \;=\; \sum \frac{M1_i - M2_i}{100} \; x \; BDi \; x \; Di$$

Where, U = total water use (mm)

u = water use in mm from the root zone for the periods between successive sampling

n = number of soil layers sampled in the root zone depth (D)

$M1_i$ = Soil moisture percentage at the time of first sampling or after irrigation in the ith layer

$M2_i$ = Soil moisture percentage at the time of second sampling or before irrigation in the ith layer

BDi = bulk density of the ith layer (g/cc)

Di = depth of ith layer of soil (cm)

Various competitive functions like aggressivity, land equivalent ratio (LER) and relative crowding coefficient (RCC) were also calculated to find out the yield advantages of the intercropping systems. Aggressivity was calculated using the following formula:

$$\text{Aggressivity } (A_{ab}) \;=\; \frac{Y_{ab}}{Y_{aa} \, X \, Z_{ab}} \; - \; \frac{Y_{ba}}{Y_{bb} \, X \, Z_{ba}}$$

Where, A_{ab} = Aggressivity of species 'a' in presence of species 'b'

Y_{ab} = Intercrop yield of species 'a' in presence of species 'b'

Y_{aa} = Pure stand yield of species 'a'

Y_{ba} = Intercrop yield of species 'b' in presence of species 'a'

Y_{bb} = Pure stand yield of species 'b'

Z_{ab} = Sown proportion of species 'a' (intercropped with 'b')

Z_{ba} = Sown proportion of species 'b' (intercropped with 'a')

LER was calculated using the below stated equation:

$$ LER = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}} $$

RCC was calculated from the following equation:

$$ K_{ab} = \frac{Y_{ab}}{Y_{aa} - Y_{ab}} \times \frac{Z_{ba}}{Z_{ab}} $$

Where, K_{ab} = Co-efficient of species 'a' in presence of species 'a'

$$ K_{ba} = \frac{Y_{ba}}{Y_{bb} - Y_{ba}} \times \frac{Z_{ab}}{Z_{ba}} $$

Where, K_{ba} = Co-efficient of species 'b' in presence of species 'a' and the yield advantage was decided from the product of the co-efficient *i.e.*, $K = K_{ab} \times K_{ba}$

And finally the economic analysis revealed the monetary advantage of the intercropping systems.

Statistical analyses of data were carried out by using MSTAT and critical differences at 5% level of significance were calculated following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth characteristics of maize and mungbean

Among the growth attributing characters, plant height, dry matter accumulation, CGR (crop growth rate) and LAI (leaf area index) of both the crops were observed (Table 2 & 3). The different frequencies of irrigation influenced the plant height of both maize and mungbean particularly during the later stages showing positive response over the rainfed treatments. Plant height increased with increased levels of irrigation at 60 and 90 DAS (days after sowing) and harvest in maize whereas in case of mungbean 60 DAS and at harvest. Among the irrigation levels, irrigation at IW: CPE ratio of 0.75 (I_3) resulted in tallest plants in both the crops and

shortest plants were observed in no irrigation without mulch. Alam et al. (1985) and Prasad et al. (1987) found increased plant growth due to frequent watering of field crops. However, plant height values in I_3 were at par with I_2 (irrigation at IW: CPE ratio of 0.50).

Among the inter cropping systems, maize and mungbean maintaining row ratio of 3:2 (C_4) recorded the maximum plant height followed by 1:1 row ratio (C_3) and sole maize (C_1). This might be due to the presence of mungbean in the intercropped situations that being leguminous in nature added to the nitrogen reserves of the soil. On the contrary, mungbean plants showed maximum plant height in sole crop (C_2) followed by C_3 and C_4 treatments where C_2 treatment, comprises of mungbean faced no competition. Irrigation had favourable influence on LAI of both the crops and I_3 (IW: CPE of 0.75) treatment maintained the greatest LAI value which increased with crop age and decreased at maturity (Table 2 and 3). Singh and Sridhar (1989) also reported similar results. Lowest LAI was recorded in rainfed and no mulch conditions. The highest LAI was shown by maize grown in 3:2 row ratio, while, sole mungbean gave maximum value at 60 DAS. CGR (crop growth rate) values of the crops showed similar trend as the leaf area indices value

Yield attributes and yields of maize and mungbean

Among the yield components, application of irrigation water at IW: CPE ratio of 0.75 (I_3) had favourable influence on LAI and dry matter accumulation resulting in greater number of cobs per plant in maize and pods per plant in mungbean (Table 4). These results were in conformity with those observed by Roy and Tripathi (1987). Length of the cob and number of grains per cob was recorded highest in I_3 treatment. Bajwa et al. (1987) also reported the same trend. However, no significant variations were observed in the test weight values of both the crops due to treatment effects, which might be the genetical characteristics of plants, although highest value was with I_3 irrigation level (Table 4).

Irrigation improved the grain and seed yield of maize and mungbean, respectively due to improvement in their yield attributing characteristics. The highest grain yield was recorded in case of I_3 irrigation level   because irrigation was given at critical physiological stages of both the crops. Similar results were reported by Trivedi et al. (1994). However in mungbean yield difference between I_3 and I_2 treatments were negligible.

With respect to the intercropping systems, treatments C_4 (3:2 row ratio) in case of maize and sole mungbean (C_2) significantly had higher values of yield components and thereby increased yield. Between the two intercropping systems, 3:2 yielded higher than of 1:1 row ratio because maize was more dominating crop than that of mungbean. The values of maize yield as affected by intercropping system were similar to that stated by Shahbazi et al. (2012).

Consumptive use (CU) of water and water use efficiency (WUE)

There was a general trend that the CU of water in both the crops either sole or intercropped increased with increasing levels of irrigation and therefore, I_3 treatment recorded the highest value of consumptive use of water (Table 5). Supply of higher levels of moisture in soil through irrigation resulted in increase in evapotranspiration losses which caused greater CU of water in both the crops. Similar observations were made by Singh et al. (2006) and Idnani et al. (2008) on mungbean. But in the present investigation, irrigation levels influenced the WUE of both the crops in respect to their crop yield. Among the sole systems, highest value of WUE recorded in I_3 in case of maize and I_2 in case of mungbean probably due to corresponding water use that produced moderate yield, resulted maximum effective utilization of water. Minimum WUE was recorded in treatment I_0.

Inter cropping systems appreciably influenced consumptive use of water (CU) by the crops which was recorded the highest in case of sole maize (252.49 mm) and lowest in sole mungbean (118.93 mm) but showed nearly equal CU as intercrops (Table 5). Among the sole systems, highest WUE was with maize, while lower value obtained with sole mungbean. CU of water increased with the increasing levels of irrigation and the maximum WUE was observed with irrigation at IW: CPE ratio 0.75 under intercropping system of maize: mungbean in 3:2 row ratio followed by IW: CPE ratio 0.50. Among the sole crop systems, maximum WUE was with IW: CPE ratio 0.75 might be due to more consumption of water corresponding to production potential of maize, while, it was more under rainfed with mulch in case of mungbean. However, among the intercropping systems, the highest was in I_3C_4 treatment combination (17.75 kg ha^{-1} mm^{-1}) followed by I_3C_3 (15.27 kg ha^{-1} mm^{-1}).

Aggressivity, Relative crowding coefficient (RCC) and Land equivalent ratio (LER)

The values of land equivalent ratios (LER) in table 6 depicts that both the intercropping systems gave highest value with irrigation at IW: CPE ratio of 0.75 and maize: mungbean at 3:2 gave more LER value than 1:1 combination. Besides, it decreased with decrease in frequency of irrigation. The treatment combination I_3C_4 gave 13% and I_3C_3 gave 8% yield advantage over the sole crop systems.

Since LER is perhaps the most appropriate measure for getting the total productivity on per unit area based on the yield of intercropping over mono-cropping at a given level of management. In this experiment maize grown in association with mungbean at 3:2 row ratio (I3C4) were found more profitable under adequate supply of irrigation water.

CONCLUSION

Results of the experiment showed that application of irrigation water and intercropping system remarkably influenced growth and yield of both the crops

which resulted in maximum with irrigation applied at IW: CPE ratio 0.75 obtaining higher value of water use efficiency. Among intercropping systems, maize-mungbean maintained in 3:2 row ratio yielded better than that of others including sole system. Aggressivity study indicated that maize was the dominant species over mungbean and more advantageous in respect to other associated characters. Thus, maize grown in association with mungbean in 3:2 row ratio was found to be more profitable and advantageous due to more land sharing under intercropping system as well as application of irrigation at IW: CPE ratio of 0.75 in new alluvial zone of West Bengal.

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Table 1. Physico-chemical properties of experimental soil (0-15 cm depth)

Soil property	Value				Method
Sand (%)	40.2				
Silt (%)	37.5				
Clay (%)	22.3				International Pipette method (Piper, 1966)
Textural class	Sandy Loam				
pH	6.45				Blackman's pH meter (Jackson, 1973)
Organic carbon (%)	0.63				Walkley and Black method, 1934
Total N content (%)	0.059				Micro-Kjeldahl's method (AOAC, 1995)
Available P (kg ha^{-1})	8.71				Olsen's method, 1954
Available K (kg ha^{-1})	104.9				Brown and Wamcke method, 1988
Bulk density (g cc^{-1})	**0-15**	**15-30**	**30-45**	**45-60**	Field method using core sampler (Dastane, 1972)
	1.45	1.47	1.49	1.52	

Table 2. Growth characteristics of maize as influenced by irrigation and intercropping system (data pooled over 2 years)

Treatments	Plant height (cm)				Leaf Area Index (LAI)				Crop Growth Rate (CGR) ($g\ m^{-2}day^{-1}$)		
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 - 60 DAS	60 - 90 DAS	90 DAS - harvest
Level of Irrigation (I)											
I_0	61.56	136.10	187.11	190.62	1.04	1.83	2.57	2.42	8.95	13.29	9.91
I_1	62.67	143.50	195.91	199.77	1.06	2.02	2.76	2.52	9.01	14.65	10.92
I_2	63.91	153.60	206.64	212.13	1.13	2.19	2.89	2.66	9.10	15.17	11.50
I_3	64.26	154.75	213.87	224.16	1.20	2.34	3.21	2.86	9.19	17.25	12.74
S.Em($\pm$)	2.011	2.656	3.571	2.968	0.038	0.070	0.096	0.054	0.568	0.350	0.527
CD(0.05)	NS	9.192	12.356	10.271	NS	0.243	0.334	0.187	NS	1.211	1.825
Cropping system (C)											
C_1	62.11	141.66	194.93	201.02	1.06	1.96	2.69	2.24	8.98	14.25	10.69
C_3	63.15	146.52	200.42	206.91	1.11	2.10	2.83	2.50	9.07	15.17	11.14
C_4	64.06	152.78	207.30	212.08	1.16	2.23	3.06	2.81	9.15	15.85	11.99
S.Em ($\pm$)	3.205	2.194	3.243	1.899	0.047	0.067	0.082	0.093	0.526	0.302	0.341
CD(0.05)	NS	6.578	9.722	5.694	NS	0.201	0.247	0.280	NS	0.907	1.023

I_0 - rainfed without mulch; I_1 - rainfed with mulch; I_2 - irrigation at IW/CPE ratio of 0.5; I_3 - irrigation at IW/CPE ratio of 0.75;

C_1 - sole maize; C_3 - maize: mungbean (1:1); C_4 - maize: mungbean (3:2); DAS - days after sowing

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Table 3. Growth characteristics of mungbean as influenced by irrigation and intercropping system (data pooled over 2 years)

Treatments	Plant height (cm)			Leaf Area Index (LAI)			Crop Growth Rate (CGR) ($g\ m^{-2}day^{-1}$)		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	01-30 DAS	30-60 DAS	60 DAS-harvest
Levels of Irrigation (I)									
I_0	16.68	28.87	29.82	2.06	2.41	1.48	2.22	4.46	2.82
I_1	17.49	32.18	33.12	2.15	2.55	1.95	2.27	4.48	2.95
I_2	18.64	34.01	35.96	2.23	3.02	2.18	2.37	4.65	3.53
I_3	19.36	35.04	36.12	2.35	3.08	2.58	2.54	4.96	3.77
S.Em (±)	0.967	1.007	1.358	0.195	0.127	0.128	0.112	0.226	0.105
CD(0.05)	NS	3.484	4.701	NS	0.440	0.442	NS	0.781	0.364
Cropping system (C)									
C_2	19.03	34.21	35.83	2.38	2.90	1.88	2.49	5.18	3.43
C_3	18.12	32.44	33.56	2.16	2.77	1.76	2.32	4.73	3.24
C_4	16.99	30.93	31.88	2.06	2.13	1.28	2.24	4.28	2.92
S.Em (±)	0.854	0.824	1.023	0.176	0.169	0.126	0.140	0.211	0.129
CD(0.05)	NS	2.470	3.068	NS	0.505	0.378	NS	0.633	0.386

I_0 - rainfed without mulch; I_1 - rainfed with mulch; I_2 - irrigation at IW/CPE ratio of 0.5; I_3 - irrigation at IW/CPE ratio of 0.75;

C_2 - sole mungbean, C_3 - maize: mungbean (1:1); C_4 - maize: mungbean (3:2); DAS - days after sowing

Table 4. Yield attributing characters, yield of maize and mungbean as influenced by irrigation and intercropping system (data pooled over 2 years)

Treatments	Maize					Mungbean				
	No. of cobs plant^{-1}	No. of grains cob^{-1}	Test wt (g)	Length of cob (cm)	Grain yield (t ha^{-1})	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test wt (g)	Pod length (cm)	Seed yield (t ha^{-1})
Levels of Irrigation (I)										
I_0	0.65	218.93	235.93	16.54	1.437	15.65	5.12	22.09	5.29	0.294
I_1	0.72	225.74	241.93	18.55	1.728	16.80	6.10	22.56	5.54	0.405
I_2	0.99	243.53	244.14	18.58	3.015	18.09	7.75	22.67	5.88	0.582
I_3	1.07	257.63	298.63	21.13	3.545	20.92	8.79	23.74	6.07	0.596
S.Em($\pm$)	0.047	5.222	3.148	0.762	0.153	1.026	0.458	0.996	0.072	0.035
C.D.(0.05)	0.161	18.072	NS	2.637	0.531	3.549	1.584	NS	0.248	0.123
Cropping system (C)										
C_1	0.59	207.88	236.35	17.45	2.970	-	-	-	-	-
C_2	-	-	-	-	-	19.56	7.68	23.11	5.91	0.804
C_3	0.76	221.13	239.83	19.94	1.928	16.48	6.38	22.95	5.69	0.347
C_4	1.23	250.37	244.31	18.72	2.396	15.55	6.21	21.80	5.48	0.257
S.Em($\pm$)	0.047	0.067	0.082	0.093	0.449	0.767	0.324	0.905	0.113	0.027
C.D.(0.05)	NS	0.201	NS	0.280	0.148	2.300	0.970	NS	0.339	0.082

I_0 - rainfed without mulch; I_1 - rainfed with mulch; I_2 - irrigation at IW/CPE ratio of 0.5; I_3 - irrigation at IW/CPE ratio of 0.75;

C_1 - sole maize, C_2 - sole mungbean, C_3 - maize: mungbean (1:1); C_4 - maize: mungbean (3:2)

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Table 5. Consumptive use (mm) and water use efficiency (kg ha^{-1} mm^{-1}) of maize and mungbean as influenced by irrigation and intercropping system (data pooled over 2 years)

Treatments	Inter cropping systems							
	Sole maize		Sole mungbean		Maize + mungbean (1:1)		Maize + mungbean (3:2)	
	CU	WUE	CU	WUE	CU	WUE	CU	WUE
Levels of irrigation (I)								
I_0	128.55	11.18	120.80	2.41	118.96	10.34	121.98	11.07
I_1	124.28	13.90	118.93	3.40	130.72	11.63	131.65	13.98
I_2	238.61	12.64	219.42	2.65	214.91	12.00	217.22	14.49
I_3	252.49	14.04	245.17	2.44	234.88	15.27	235.69	17.75

I_0 - rainfed without mulch; I_1 - rainfed with mulch; I_2 - irrigation at IW: CPE ratio of 0.5; I_3 - irrigation at IW: CPE ratio of 0.75;

CU - consumptive use of water; WUE - water use efficiency and C_1 - sole maize, C_2 - sole mungbean, C_3 - maize : mungbean (1:1); C_4 - maize : mungbean (3:2)

Table 6. Competitive functions of maize and mungbean intercropping system as influenced by irrigation (data pooled over 2 years)

Treatments	Intercropping systems											
	Maize + Mungbean (1:1)						Maize + Mungbean (3:2)					
	A_{MS}	A_{SM}	LER	K_{MS}	K_{SM}	K	A_{MS}	A_{SM}	LER	K_{MS}	K_{SM}	K
Levels of irrigation (I)												
I_0	+0.31	-0.31	1.05	1.56	0.82	1.27	+0.40	-0.40	1.09	1.85	0.77	1.42
I_1	+0.36	-0.36	1.06	1.66	0.80	1.32	+0.47	-0.47	1.10	2.12	0.74	1.56
I_2	+0.43	-0.43	1.07	1.85	0.75	1.38	+0.56	-0.56	1.11	2.55	0.70	1.78
I_3	+0.51	-0.51	1.08	2.07	0.71	1.46	+0.64	-0.64	1.13	3.14	0.64	2.00

I_0 - rainfed without mulch; I_1 - rainfed with mulch; I_2 - irrigation at IW/CPE ratio of 0.5; I_3 - irrigation at IW/CPE ratio of 0.75;

A_{MS} - aggressivity of maize on mungbean; A_{SM} - aggressivity of mungbean on maize; LER - land equivalent ratio; K_{MS} - co-efficient of maize in presence of mungbean; K_{SM} - co-efficient of mungbean in presence of maize.