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Effect of supplemental irrigation on yield and water productivity of dry season crops in Andaman and Nicobar Islands

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ABSTRACT

Field experiments were conducted with different supplemental irrigation levels for growing maize, greengram, sesame, okra and chilies during the dry season of 2006–07 and 2007–08 in A & N Islands. The results indicated that though the yields achieved with supplemental irrigation has not achieved at par with that of farmers, practice (I_5) of irrigating the crop as and when required (4 160 and 10 398 kg/ha during 2006–07 and 2007–08 respectively), it has increased the yield significantly in both the years vis-à-vis I_0 i e, no irrigation (1 355 and 5 640 kg/ha during 2006–07 and 2007–08 respectively). The percent yield increase over I_0 when supplemental irrigation was provided one (I_1), two (I_2), three(I_3) and four (I_4) times due to supplemental irrigation was 48, 95, 133 and 178 in I_1, I_2, I_3 and I_4 during 2006–07 and 13, 27, 53, 62 in I_1, I_2, I_3 and I_4 during 2007–08 respectively. Thus by providing supplemental irrigation at different critical crop growth stages, higher yield and economic returns were achieved with lesser irrigation water usage, an important consideration for raising dry season crops in the rice fallows from the harvested rainwater of rainy season under Island conditions. However, the results also underlined the fact that cultivation of vegetables like okra and chillies on residual soil moisture alone without irrigation during dry season in the islands may be riskier and result in economic loss if the rainf all during the cropping period is very low.

Keywords: Chilies, Dry season crops, Greengram, Maize, Okra, Sesame, Supplemental irrigation, Water productivity

Land and water are two critically important resources, the efficient management of which is vital for economic growth and development. Andaman and Nicobar Islands constitute a group of 572 Islands in the Bay of Bengal and fall under the Agro-ecological region 20 (hot humid to per-humid Island eco-region). Out of the geographical area of 8 249 km^2 around 90% is covered under forest including deemed forest and area under agriculture accounts to 6 % of the total area, i e 50 000 ha approximately. Of which 12 000 ha (flat land) is cultivated to paddy and other field crops and 38 000 ha (hilly land) was under plantation and other crops (Anonymous 2006). The agricultural production scenario has been less than satisfactory in these islands with a cropping intensity of 133 % (2005–06) and much remains to be done for harnessing the land and water resources and achieving targeted yields. Though farmers are habituated with mono cropping of traditional low-yielding long-duration rice variety (C 14-8), there is ample scope for increasing the cropping intensity by growing a number of crops, especially vegetables in rice fallows during dry months. This will be possible only by adoption of proper dry season farming technologies and the land can be brought under double cropping through proper utilization of residual soil moisture and by providing supplemental irrigation to the dry season crops from harvested rainwater (Wani *et al.* 2003, Kar *et al.* 2004) as these Islands receive around 3 000 mm annual rainfall with a surplus of about 1 530 mm from middle of May to middle of December and experience a deficit of about 610 mm during the remaining part of the year. When natural contributions by rainfall or groundwater are infrequently unable to satisfy full crop water requirements, a continuously optimal water regime can be obtained by supplemental irrigation, i e, by a temporary and discontinuous irrigation regime (Caliandro and Boari 1996).

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In regions where irrigation resources are too limited for ensuring a permanent optimal water regime to crops, supplemental irrigation is mainly supplied at the critical periods of the crop growth cycle to maintain or improve crop production (Debaeke and Aboudrareb 2004, Sharma *et al.* 2010). Hence, an attempt was made to raise dry season (December – April) crops in A & N Islands with supplemental irrigation at different critical crop growth stages in order to increase the land and water productivity and profitability.

MATERIALS AND METHODS

Field experiments were conducted in rice fallows of Bloomsdale farm of Central Agricultural Research Institute, Port Blair, A & N Islands during the dry season of 2006–07 and 2007–08. The soil was sandy clay loam and low in available N and medium in available P and K (218: 15.7: 273 kg N:P:K/ha during 2006–07 and 221: 16.1: 265 kg N:P:K/ ha during 2007–08, respectively). To estimate the amount of rainfall likely to occur in the dry season, historical weather data (1970 – 2003) was collected from India Meteorological Department, Pune and the weekly rainfall data were analyzed for computation of weekly probable rainfall amount at 10, 20, 30, 40, 50, 60, 70, 80 and 90 % probability level following the work done by Bhakar *et al.*(2008) using Weibull's equation:

$$P = m/(n+1)$$

where, P is the probability of occurrence; m is the rank of the observed rainfall value after arranging them in descending order of magnitude and n is the total number of years of record.

The field was prepared after harvest of the rice crop and layout was made using split-plot design to accommodate different crops (maize (*Zea mays*), greengram (*Vigna radiata*), sesame (*Sesamum indicum*), okra (*Abelmoschus esculentus*) and chilies (*Capsicum annuum*)) in the main plots and the supplemental irrigations (I_0: no irrigation, I_1: one, I_2: two, I_3: three, I_4: four irrigations and I_5: farmers' practice of irrigating as and when required) in the sub-plots and replicated thrice. Maize, greengram, sesame and okra were sown and chilies was transplanted on 11 December 2006 and 29December 2007 respectively. Supplemental irrigation (5 cm irrigation depth/irrigation) was given at critical crop growth stages as given in Table 1. The important packages of practices adopted are detailed in Table 2.

The sampling techniques for all the growth and yield characters including estimation of yield were followed as per standard procedures. The yield of different crops were converted into maize equivalent yield (MEY) using the following formula and analysis of variance was done using SAS v 9.2.

$$MEY = \frac{\Sigma Yi\ .\ Pi}{P(p)}$$

where, Yi = Yield of different crops; Pi = price of respective crops and P(p) = price of maize.

The MEY were worked out using cost of maize grain @ ₹ 10 000/tonne greengram and sesame @ ₹ 25 000/tonne, okra @ ₹ 12 000/tonne and green chilies @ ₹ 22 000 /tonne. The total water productivity (TWP) of different crops was determined by dividing the crop yield by the total water used (i e, supplemental irrigation water + rainfall) while the gross

Table 1 Supplemental irrigation provided at different crop growth stages

Crop	Supplemental irrigation levels				
	I_1	I_2	I_3	I_4	I_5
Maize	TI	TI and GF	KHS, TI and GF	KHS, TI, Early GF and M	Eight irrigations
Greengram	F	F and PS	Pre-F (25 DAS), F and PS	Pre-F, F, Early PS and Early M	Six irrigations
Sesame	F	F and PS	4-5 leaf stage (25 DAS), F and PS	4-5 leaf stage, F, Early PS and Early M	Six irrigations
Okra	F	F and FF	EVS, F and FF	EVS, F, FF – 1 and FF - 2	12 irrigations
Chilies	F	F and FF	EVS, F and FF	EVS, F, FF – 1 and FF - 2	12 irrigations

TI, Tassel initiation; F, flowering; GF, grain filling; PS, pod setting; FF, fruit formation; KHS, knee-high stage (20–25 days after sowing); EVS, early vegetative stage (20–25 days after sowing/transplanting); M, maturity

Table 2 Package of practices adopted for the post-monsoon crops

Crop	Variety	Spacing (cm)	Fertilizer * (kg N:P:K/ha)	Rainfall received (mm)		Date of harvest	
				2006–07	2007–08	2006–07	2007–08
Maize	HQPM-1	60 × 20	120:60:40	34.4	186.7	29/03/07	16/04/08
Greengram	PDM 139	30 × 10	25:50:0	34.4	95.3	Staggered	Staggered
Sesame	Local	30 × 30	35:23:23	34.4	95.3	08/03/07	27/03/08
Okra	Hybrid	45 × 30	40:50:30	34.4	149.7	Staggered	Staggered
Chillies	Hybrid	45 × 30	60:60:30	34.4	186.7	Staggered	Staggered

* In I_{1-5}, full dose was applied as basal + top dressing while in I_0, only half of the dose was applied as basal

irrigation water productivity (GIWP) was worked out as the ratio of increase in yield (over control) to the gross depth of supplemental irrigation applied and expressed in kg MEY/m^3 (Oweis and Hachum 2006).

RESULTS AND DISCUSSION

Weekly probability of rainfall during dry season

From the weekly rainfall probability analysis (Table 3) it can be inferred that the chances of getting rainfall during the dry season at most dependable probability level of 70% is 11.4 mm from December to April. Even at 50% probability level, around 63 mm rainfall can be expected during the same period indicating the possibility of occurrence of this quantity in alternate years. The coefficient of variation of more than 150% in most of the Meteorological Standard Weeks also indicates higher rainfall variability during this period. The above facts clearly indicate the need of supplemental irrigation during dry season for achieving higher crop yields. Dennett (1987) also emphasized the importance of considering rainfall in terms of probability of occurrence to assess the long-term suitability of crop cultivars and crop management strategies.

Effect of supplemental irrigation on crop yield

Among the crops, vegetables (okra and chillies) performed better than other crops (maize, sesame and greengram) in both the years (Table 4). During 2006–07, okra recorded the highest MEY (4 689 kg/ha), followed by chillies (3 352 kg /ha)and maize (2 544 kg/ha) while sesame (1881 kg/ha) and greengram (1 769 kg/ha) recorded significantly lower MEY yields. However, in 2007–08, okra (14 722 kg/ha) and chillies (14 606 kg/ha) recorded significantly higher MEY, followed by maize (4 927 kg/ha) and sesame (3 584 kg/ha) while greengram (1 605 kg/ha) recorded the lowest MEY.

The results also revealed that supplemental irrigation has resulted in significantly higher MEY in all the crops vis-à-vis I_0 (no irrigation). In both the years, though supplemental irrigation has not achieved on par MEY with that of I_5 (4 160 and 10 398 kg/ha during 2006–07 and 2007–08 respectively), it has resulted in significantly higher MEY than that of I_0 (1 355 and 5 640 kg/ha during 2006–07 and 2007–08 respectively). The distinct variation in the MEY of crops between the years and lesser crop response to irrigation levels during 2007–08 vis-à-vis 2006–07 could be attributed to the higher amount of rainfall received during the cropping period (Table 2) which might have provided a much better available soil moisture and microclimate to the crops in general during 2007–08 compared to 2006–07.

Perusal of data also revealed that supplemental irrigation has significantly increased the MEY levels of vegetables in both the years. In okra and chilies, per cent increase in MEY

Table 3 Expected weekly rainfall during dry season at different probability levels

MSW*	Week ending on	Normal RF (mm)	SD**	CV‡ (%)	Rainfall (mm) at probability levels of 10%	20%	30%	40%	50%	60%	70%	80%	90%
48	2 Dec	36.5	43.5	119	90.6	59.6	42.5	30.7	21.9	14.9	9.3	4.7	1.2
49	9 Dec	32.4	62.0	192	100.9	55.1	32.2	17.6	7.9	1.2	0	0	0
50	16 Dec	35.0	95.4	272	65.8	19.7	7.6	4.7	4.5	3.2	0	0	0
51	23 Dec	9.3	22.7	245	21.7	8	3.3	1.5	0.9	0.8	0.6	0	0
52	31 Dec	40.3	114.0	283	123.8	47.1	16.4	1.5	0	0	0	0	0
1	7 Jan	13.0	29.6	222	51.4	38.2	28.9	20.8	13.3	5.8	0	0	0
2	14 Jan	5.1	32.6	250	45.5	21.6	10.4	3.7	0	0	0	0	0
3	21Jan	4.3	15.6	309	16.8	6.2	1.9	0	0	0	0	0	0
4	28 Jan	3.3	14.9	349	11.4	2.9	0.2	0	0	0	0	0	0
5	4 Fec	8.0	10.4	317	10.7	3.8	1.0	0	0	0	0	0	0
6	11Feb	2.2	33.4	417	13.3	0.9	0	0	0	0	0	0	0
7	18 Feb	3.9	7.2	331	4.8	1.1	0.1	0	0	0	0	0	0
8	25 Feb	2.3	14.6	374	10.6	2.4	0	0	0	0	0	0	0
9	4 Mar	3.1	5.3	229	8.3	4.4	2.4	1.1	0.2	0	0	0	0
10	11Mar	2.0	7.3	234	11.1	5.8	3.1	1.4	0.2	0	0	0	0
11	18 Mar	6.5	5.9	294	8.1	3.7	1.6	0.4	0	0	0	0	0
12	25 Mar	12.4	21.6	334	22.8	8.1	2.2	0	0	0	0	0	0
13	1 Apr	2.5	42.4	341	40.7	13.1	2.6	0	0	0	0	0	0
14	8 Apr	9.3	6.9	274	8.7	3.8	1.6	0.4	0	0	0	0	0
15	15 Apr	8.9	17.8	192	28.5	15.4	8.9	4.8	2.2	0.4	0	0	0
16	22 Apr	42.1	19.4	218	29.4	15.1	8.1	3.8	1.1	0	0	0	0
17	29 Apr	41.0	76.8	183	118.5	62.2	35.7	20.1	10.5	4.6	1.5	0.4	0
18	6 May	55.4	47.4	115	102.9	70.9	52.3	38.7	28	18.9	10.8	3.4	0

* Meteorological standard week; SD**, standard seviation; CV‡, coefficient of variation

due to I_1, I_2, I_3 and I_4 was in the tune of 37, 105, 146, 251 and 94, 188, 253, 319 during 2006–07 and 6, 20, 43, 48 and 19, 27, 69, 88 during 2007–08, respectively. This clearly indicates the importance of supplemental irrigation for vegetable cultivation at critical crop growth stages, viz early vegetative stage, flowering and fruit formation stages under island ecosystem especially during low rainfall year (2006–07). In case of maize, providing supplemental irrigation resulted in significant increase in MEY over I_0 to the tune of 65, 99, 152 and 161% during 2006–07 and 19, 20, 33 and 37% during 2007–08, respectively. Similar effect of supplemental irrigation on yield of different winter crops (maize, groundnut, sunflower, wheat and potato (tuber)) of Eastern India was reported by Kar *et al.* (2006). Sesame also responded well and providing supplemental irrigation at 4–5 leaf stage (25 DAS), flowering and pod setting resulted in 61 and 97% increase in MEY over I_0 during 2006–07 and 2007–08, respectively. However, green gram did not show much response to supplemental irrigation especially during higher rainfall year (2007–08) and resulted in lesser quantum of MEY increase. This indicated that green gram can be grown in the rice fallows with the available residual soil moisture itself and only when if the rainfall is very less as was in the case of 2006–07, then supplemental irrigation can be provided at flowering and pod setting stages.

Effect of supplemental irrigation on economic returns

The present investigation clearly indicated that higher economic returns in respect of dry season crops could be achieved under island ecosystem by providing supplemental irrigation at different critical crop growth stages (Table 4). Maximum net returns were obtained with I_5 while the lowest net returns were obtained with I_0 in all the crops. In 2006–07, okra receiving 12 irrigations (I_5) registered the highest net return of ₹ 52 070 followed by I_4 (₹ 45 170) and in 2007–08, chilies with I_5 recorded the highest net return of ₹ 1 81 594 followed by I_4 (₹ 1 29 044). The higher B : C ratio achieved with I_3 in maize, sesame and, green gram indicated that with few irrigations one can achieve higher economic returns over I_0 in these crops. In case of vegetables, providing four supplemental irrigations has produced much higher net returns than I_0 and net returns comparable to that achieved with I_5 which had 12 irrigations during the cropping period. The results also underlined the fact that vegetable cultivation without any assured irrigation in the islands may be risky and result in economic loss if the rainfall during the

Table 4 Effect of supplemental irrigation on maize equivalent yield (kg/ha), net returns (₹/ ha) and B : C ratio of dry season crops

Crop/supplemental	Maize		Green gram		Sesame		Okra		Chilies (Green)		Mean	
irrigation level	2006–07	2007–08	2006–07	2007–8	2006–07	2007–8	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08
Maize equivalent yield (kg/ha)												
I_0	1 207	3 906	1 220	1 460	1 290	2 083	1 967	11 532	1 093	9 222	1 355	5 640
I_1	1 988	4 635	1 538	1 522	1 695	2 570	2 689	12 204	2 121	10 967	2 006	6 380
I_2	2 406	4 687	1 800	1 583	1 810	3 922	4 026	13 836	3 148	11 682	2 638	7 142
I_3	3 039	5 182	1 968	1 762	2 072	4 107	4 829	16 536	3 854	15 550	3 152	8 628
I_4	3 151	5 365	2 028	1 628	2 183	4 340	6 901	17 028	4 583	17 362	3 769	9 145
I_5	3 472	5 787	2 060	1 675	2 238	4 480	7 720	17 196	5 313	22 851	4 160	10 398
Mean	2 544	4 927	1 769	1 605	1 881	3 584	4 689	14 722	3 352	14 606		
Net returns (₹/ha)												
I_0	7 557*	30 791	6 798	8 370	8 035	15 132	–466	82 720	–9 256	65 454		
	(2.05)	(4.72)	(2.26)	(2.34)	(2.65)	(3.66)	(0.98)	(3.54)	(0.54)	(3.45)		
I_1	13 818	35 416	8 702	7 525	11,237	18 960	4 869	74 760	–1 034	67 950		
	(2.44)	(4.24)	(2.30)	(1.98)	(2.97)	(3.81)	(1.22)	(2.58)	(0.95)	(2.63)		
I_2	18 201	35 287	11 113	7 735	12 173	32 095	17 488	90 040	8 170	74 060		
	(2.82)	(4.05)	(2.61)	(1.96)	(3.05)	(5.50)	(1.77)	(2.86)	(1.35)	(2.73)		
I_3	24 808	39 585	12 467	9 015	14 370	33 295	24 874	116 780	14 911	111 826		
	(3.38)	(4.23)	(2.73)	(2.05)	(3.26)	(5.28)	(2.06)	(3.40)	(1.63)	(3.56)		
I_4	25 916	40 888	12 853	7 275	15 149	35 100	45 170	121 440	21 765	129 044		
	(3.41)	(4.20)	(2.73)	(1.81)	(3.27)	(5.23)	(2.89)	(3.49)	(1.90)	(3.89)		
I_5	29 968	43 682	12 750	7 750	15 164	35 590	52 070	122 080	27 678	181 594		
	(3.60)	(4.08)	(2.62)	(1.86)	(3.10)	(4.86)	(3.07)	(3.45)	(2.09)	(4.87)		
CD (P=0.05)	2006-07	Crop	Irrigation	C at I	I at C		2007-08	Crop	Irrigation	C at I	I at C	
for MEY		290.3	122.8	382.6	274.5			1114.3	254.7	1174.5	569.5	

Table 5 Effect of supplemental irrigation on water productivity of dry season crops

Crop/supplemental irrigation level	Maize		Greengram		Sesame		Okra		Chillies	
	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08	2006–07	2007–08
Total water productivity (kg MEY/m^3)										
I_1	2.36	1.96	1.82	1.05	2.01	1.77	3.19	6.11	2.51	4.63
I_2	1.79	1.63	1.34	0.81	1.35	2.01	3.00	5.54	2.34	4.07
I_3	1.65	1.54	1.07	0.72	1.12	1.67	2.62	5.52	2.09	4.62
I_4	1.34	1.39	0.87	0.55	0.93	1.47	2.94	4.87	1.96	4.49
I_5	0.80	0.99	0.62	0.57	0.67	1.13	1.22	3.13	0.84	3.89
Gross irrigation water productivity (kg MEY/m^3)										
I_1	1.56	1.46	0.64	0.13	0.81	0.98	1.44	1.34	2.06	3.49
I_2	1.20	0.78	0.58	0.12	0.52	1.84	2.06	2.30	2.06	2.46
I_3	1.22	0.85	0.50	0.20	0.52	1.35	1.91	3.34	1.84	4.22
I_4	0.97	0.73	0.40	0.08	0.45	1.13	2.47	2.75	1.75	4.07
I_5	0.57	0.47	0.28	0.11	0.32	0.80	0.96	1.42	0.70	3.41

cropping period is very low as in the case of 2006–07. The probable rainfall expected during the period in A&N Islands (Table 3) also strongly supports this as not much rainfall (11.4 mm) is expected from December to April at 70% probability level.

Effect of supplemental irrigation on water productivity

Among the crops, vegetables produced higher MEY/m^3 of water applied than other crops (Table 5). Okra registered the highest TWP of 3.19 and 6.11 kg MEY/m^3 during 2006–07 and 2007–08, respectively while greengram recorded the lowest TWP of 0.62 and 0.57 kg MEY/m^3 during the corresponding period. In case of GIWP, okra registered the highest (3.34 kg MEY/m^3) while greengram recorded the lowest (0.28 kg MEY/m^3) during 2006–07 and chillies registered the maximum of 4.22 kg MEY/m^3 while greengram recorded the lowest of 0.11 kg MEY m$^{/3}$ during 2007–08, respectively. This clearly indicates the advantage of growing vegetables in dry season during which water availability was limited for achieving higher water productivity.

Thus, it can be concluded that by providing supplemental irrigation at critical crop growth stages (knee-high, tassel initiation and grain-filling stages of maize, flowering and pod setting stages of greengram, 4–5 leaf stage, flowering and pod setting stages of sesame, early vegetative, flowering and fruit formation stages of okra and chillies) one can achieve increased yield and higher profitability as well as increased land and water productivity. In addition, the risk of crop failure in dry season during low rainfall years can also be minimized under island eco system. However, farmers should consider the availability of other resources like inputs, labour, investment capacity, etc., at their disposal before apportioning their land into different crops though cultivation of vegetable crops with supplemental irrigation gives higher returns than other crops.

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