IMPACT OF CANOPY MANAGEMENT ON BIO-ECONOMIC EFFICIENCY OF CHICK PEA (*CICER ARIETINUM* L.) UNDER ARID CONDITIONS

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ABSTRACT

A study was conducted at Arid Zone Research Institute, Bhakkar, Pakistan during 2007-10 to observe the impact of canopy management on bio-economic efficiency of chickpea on sandy loam soil. Treatmetns comprising plant growth regulators i.e. Nephthalene Acetic Acid (NAA) was kept in main plots while four available moisture depletion levels (ASMDL 50, ASMDL 65, ASMDL 80 and ASMDL 95) were kept in sub-plots, using split plot arrangements. Naphthalene acetic acid (4.5% as sodium salt) was applied @ 600 ml per hectare at 90, 110, 130, 150 and 165 days after sowing. The results showed that NAA applied at flower blooming stage (90 days after sowing) significantly increased number of pods per plant, seeds per pod , 100-seed weight and seed yield by 12.50, 6.98, 9.59 and 13.98 percent, respectively compared with control (NAA_0). Treatment combination NAA_1 x $ASMDL_{80}$ gave maximum pods per plant (70.68), 100-seed weight (30.15 g) and grain yield (3219.1 kg/ha). Water productivity ranged from 8.23 ($ASDML_{50}$ x NAA0) to 18.18 kg per ha per min (NAA x ASSML95). Maximum dry matter accumulation was recorded at 150 DAS in case of both NAA levels. The application of 600 ml per hectare NAA at flower initiation and maintenance of irrigation at 80 percent ASMDL (total amount of water applied was 252 mm with irrigation depth of 126 mm each) proved best for higher chickpea seed yield with 4.28 BCR.

KEYWORDS: ***Cicer arietinum;*** **naphthalene acetic acid; soil moisture levels; canopy management; bio-economic efficiency; Pakistan.**

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is widely grown in arid and semi-arid regions where its yield is governed by available moisture level during growth period. Trend of plant growth regulators use such as naphthalene acetic (NAA) is

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getting higher interest therefore it is being used over million of hectares worldwide. Napthalene acetic acid as aynthetic auxin, promotes cellular elongation, root development, helps for DNA replication (20), reduces the flower fall, increases pods per plant, grains per pod and ultimately yield of chickpea. Pods per plant, grains per pod and pod weight in chickpea were increased with 25-50 ppm NAA at five days interval starting at flowering stage.

In same context Bai *et al*. (7) observed a significant increase in yield and yield component of *Vigna radiata* with the application of eight foliar sprays of NAA @ 25 mg per liter at seven days intervals starting at flowering. The highest yield (2.35 t/ha) of chickpea was achieved with 20 ppm of NAA when sprayed at bud initiation and pod formation stages (25). NAA supplied at 50% flowering, increased pods per plant and pod weight per plant while decreased the flowers drop.

Chickpea is acclimatized to wide range of soils and environmental conditions. Soil moisture depletion is the primary cause of decrease in crop growth and hence yields. The potential evapotranspiration of chickpea crop ranges from 204-280 mm (21) and the consumptive use of water based on water balance in root zone should be 247-290 mm (15). Increase in water use from 4.8 to 10.6 kg per ha per mm exhibited an increase in chickpea yield (18). In this scenario, measurement of available soil moisture level is helpful for increasing water productivity and hence yields. Chickpea irrigated at 15, 30 or 45 percent available soil moisture at 1, 2 and 3 irrigations, respectively exhibited maximum yield with two irrigations (23). Dry matter accumulation and seed yield per unit area decreased under drought and water deficit conditions (8, 14). Scheduling irrigation at critical growth stages saves 2.3 cm water compared with un-scheduled irrigation in chickpea (9). However, unnecessary irrigations decreased yield and yield components causing the wastage of irrigation water (16). On the other hand, chickpea gave double yield under irrigated conditions than that of un-irrigated (26).

Maximum biological yield of chickpea was recorded at 80 percent ASMDL (3). Chickpea when subjected to high (50% available) and low (90% available) water stress, produced 8-19 percent higher seed yield at low moisture stress compared with high moisture stress (13). Maximum chickpea yield was recorded at 80 percent available soil moisture depletion level (2).

Crop canopy plays an important role in crop growth and productivity. Imbalanced crop canopy hinders photosynthetic activities by mal penetration and interception of light, branching pattern, flowering intensity and grain formation. The prime factor which controls crop canopy is the availability of soil moisture. Excessive soil moisture not only leads to wastage of water and nutrients but also increases the risk of crop lodging.

The objective of the present study was to manage crop canopy and conserve irrigation water for better economic efficiency of chickpea under arid environmental conditions.

MATERIALS AND METHODS

This study was conducted (031^0 35-24.13-N and 071^0 08-47.21-E) during 2007-08, 2008-09 and 2009-10 on sandy loam soil (Table 1).

Table 1. Physico-chemical characteristics of experimental site (sandy loam soil) at Arid Zone Research Institute, Bhakkar, Punjab, Pakistan.

Physico-chemical characteristics	Unit	Values			
		Before sowing	2007-08 (After harvest)	2008-09 (After harvest)	2009-10 (After harvest)
pH	-	8.2	8.0	8.0	8.0
EC	dS m^{-1}	0.44	-	-	-
Available P	ppm	3.34	3.20	2.90	2.75
Available K	ppm	66.00	55.00	60.0	60.00
Organic matter	%	0.27	0.32	0.34	0.35
N	%	0.014	0.016	0.017	0.018
Field capacity	% by volume	14.60	14.65	14.67	14.67
Bulk density	g m^{-3}	1.26	1.26	1.26	1.26
Permanent wilting point	% by volume	5.40	5.40	5.40	5.40

The seed of chickpea variety, Bittle-98, was sown through single row drill at row spacing of 30 cm. After 30 days of sowing, thinning was done to establish 10 cm plant to plant distance. The crop was inter-cultured twice at 35 and 70 days after sowing (DAS). The weather data during experimental period are presented in Table 2.

Layout of experiment was RCBD with split plot arrangements having four replications. The crop was sown on recommended sowing time i.e. 20^{th} October each year. Treatments comprising of control (NAA_0) and NAA applied (NAA_1) (4.5% as sodium salt) were kept in main plots while four available soil moisture depletion levels were kept in sub-plots. NAA was applied uniformly with Knapsack sprayer @ 600 ml/ha at 90 days after sowing (flower initiation). Four available soil moisture depletion levels were included i.e. $ASMDL_{50}$ (50%), $ASMDL_{65}$ (65%), $ASMDL_{80}$ (80%) and $ASMDL_{95}$ (95%). The recommended dose of N (22.0 kg/ha) and P (57.0

kg/ha as P_2O_5) was applied in the form of urea and triple super phosphate, respectively at sowing. The sub-plot size was 2.4 × 5 m. Water holding capacity of experimental soil (sandy loam) was very low and sufficient moisture was not available to ensure even germination. Therefore, an irrigation of 10 cm was applied as seed priming to ensure the uniform and rapid germination.

Table 2. Meteorological data recorded during experimental period for three consecutive years (2007-08, 2008-09 and 2009-10).

Month	**2007-08**			
	Mean Temperature (°C)		**Relative humidity (%)**	**Rainfall (mm)**
October	29.03	14.48	81.45	9
November	24.06	9.46	80.1	-
December	20.93	5.03	79.61	17
January	16.32	2.7	74.71	10
February	16.46	6.35	83.07	-
March	24.5	12.19	80.7	-
Total	-	-	-	**36**
	2008-09			
October	32.38	15.5	82.32	-
November	25.8	8.5	78.19	-
December	20.38	1.67	70.77	-
January	18.29	2.58	74.94	4
February	24.42	8.96	77.39	9
March	25.67	11.22	79.35	15
Total	**-**	**-**	**-**	**28**
	2009-10			
October	32.83	17.16	82.45	10
November	22.63	11.76	81.1	-
December	18.03	5.54	79.7	8
January	18.35	2.8	75.71	0
February	18.92	7.67	82.07	8
March	22.9	11.25	82.7	6
				32

The first post planting irrigation was applied 50 days after germination and subsequently desired available soil moisture levels were maintained in the respective plots.

The first post planting irrigation was applied at 50 days after sowing and subsequently desired available soil moisture levels were maintained in the respective plots.

Soil sampling and determination of moisture contents

Moisture contents of the soil were determined by gravimetric method. Keeping in view the weather conditions from 3rd week of December to 3rd week of March, soil samples for moisture determination were taken regularly at 5-10 days interval. For moisture estimation, three replications of soil samples were collected from i.e. 0-30, 31-90 and 91-150 cm depth (22) from each sub-plot. Moisture of each sample was calculated separately and average was calculated. Soil moisture contents were determined as O_W (%) = (Ws_1 - Ws_2)/ Ws_2× 100 (U.S. Salinity Lab. Staff, 1954), whereas Ow, Ws_1 and Ws_2 represent soil moisture percentage on oven dry weight basis, soil sample weight before oven drying (g) and soil sample weight after oven drying (g), respectively.

Available soil moisture contents on volume basis at different depletion levels were calculated as proposed by Penman (19) and French and Legg (12), ASMDL= (Fc-θi) 100/Fc-PWP, where PWP, θi and Fc were the permanent wilting point, soil moisture contents in percent by volume before irrigation and field capacity respectively shown in Table 3.

Table 3. Depth of irrigation applied to different ASMDL and total amount of water applied.

ASMDL	Critical soil water contents at irrigation (% volume)	Depth of Irrigation (mm)	Total amount of water applied + ppt (mm)			
			2006-07	2007-08	2008-09	Average
ASMDL50 (50%)	10.00	69	312	304	308	308
ASMDL65 (65%)	8.62	90	306	298	302	302
ASMDL80 (80%)	7.24	110	256	248	252	252
ASMDL95 (95%)	5.86	131	167	159	163	163

Irrigation was applied to respective plots as soon as the desired available soil moisture depletion level obtained in the crop root zone by adapting straight border irrigation system.

Soil moisture contents prior to irrigation (θi) were computed by the equation Pb = Wd/Vi (10), where Pb represents bulk density of soil (g/cm^3), Wd denoted weight of oven dried soil (g) and Vi denoted total volume of soil and voids (cm^3).The percent moisture contents on volume basis were determined by following U.S. Salinity Lab. Staff (1954) formula i.e. Ov(%) = (Pb ×Ow)/Pw where Ov(%), Pb and P_W are soil moisture content on volume basis (%), bulk density of soil (g/cm) and density of water (g/cm), respectively.

Irrigation

Crop was irrigated at critical soil moisture contents (θi) to bring back the root zone to field capacity. Depth of irrigation for each ASMDL (Table 3) was directly measured by field sampling method of crop water requirement by equation (Dw= Drz(Fc-Oi)/100 (17), where Dw is the depth of water to be applied (mm), Drz is depth of root zone (150 cm). Quantity of water applied to each treatment was measured by installation of cut throat flume (8"× 3').

The time required to obtain the desired depth of irrigation for each plot was calculated by Hoffman *et al.* (17) equation; t = KADw/q, where t, Dw, A, q and K are the time required for irrigation in minutes, depth of water to be applied (mm), area in m^2, discharge (L/sec) and K - constant (1/6 for t, dw, A and q) respectively.

Fresh biomass of five randomly selected plants on fortnightly basis was measured and a total of five readings were recorded for the assessment of dry matter accumulation. Plants were washed with water and air dried followed by oven drying at 70ºC till constant weight to determine dry matter accumulation (DMA).

Plant growth parameters like height (cm), pod bearing branches per plant and number of pods per plant were recorded from 10 randomly selected plants from each plot and average number of seeds per pod were recorded from 20 randomly selected pods taken from 10 randomly selected plants. Flower duration was calculated by subtracting days to 50% flowering from days to flower termination. Average weight of 100 seeds was recorded for each treatment whereas grain yield (kg/ha) was recorded on sub-plot basis leaving side rows as non-experimental. Water productivity was calculated following the ASCE (1978) procedure WP (kg/ha/mm) = grain yield (kg)/water applied (mm/ha). Benefit cost ratio (total income/total expenditure) was calculated (6). Data were subjected to statistical analysis (24) to determine the differences between treatments by using statistic software package "Statistix 8.1". Tukeys test was applied for the comparison of individual treatments.

RESULTS AND DISCUSSION

Dry matter accumulation

Increase in dry matter accumulation is one of the criterions of crop growth. The Fig. 1 is showing dry matter accumulation NAA and treatment combination, (NAA_1 × $ASMDL_{80}$) presented better results over control (NAA_0 × $ASMDL_{95}$). The maximum dry matter was accumulated in plots treated with NAA at 150 days after sowing (DAS) which reflected that NAA has increased the dry matter accumulation (DMA) by increasing crop growth rate.

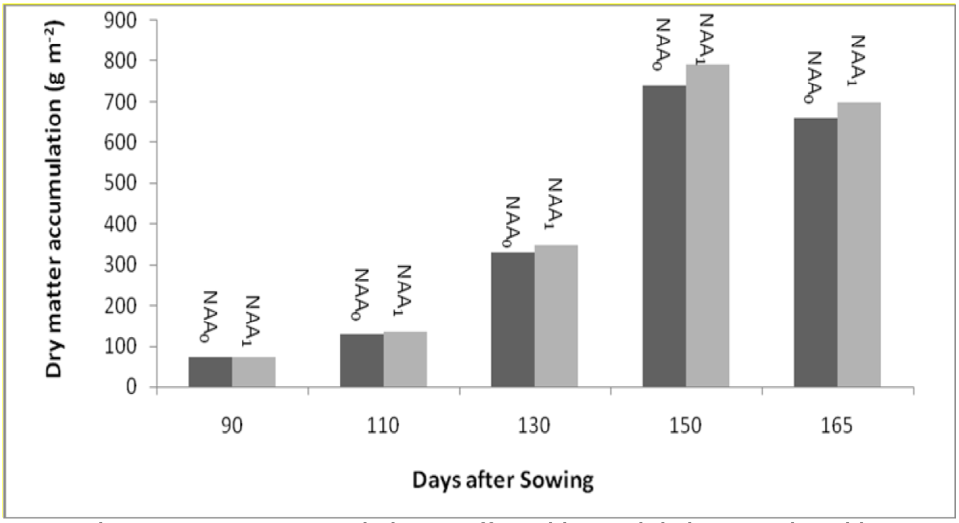

Fig.1. Dry matter accumulation as affected by Naphthalene Acetic Acid (3 years pooled data)

Differential behavior of available soil moisture depletion levels was observed toward DMA starting from 110 DAS. Maximum rate of dry matter accumulation was observed from 130 to 150 DAS (reproductive stage). The treatment combination, NAA_1×$ASMDL_{80}$ accumulated the maximum dry matter with average higher crop growth rate of 15.42 g/m/day (Table 4) while minimum values for dry matter were observed in $ASMDL_{95}$ (Fig.2) whereas treatment combination NAA_0 ×$ASMDL_{95}$ exhibited the least average crop growth rate of 10.58 g m^{-2} day^{-1}.

Table 4. Effect of NAA and ASMDL on crop growth rate (g/m^2/day) of chickpea (Pooled data of 3 years).

	Days after Sowing (DAS)					Average CGR
Treatments	**100**	**115**	**130**	**145**	**160**	
NAA_I x $ASMDL_{80}$	8.39a	11.14a	15.31a	17.87a	24.37a	15.42
NAA_0 x $ASMDL_{80}$	8.10a	8.90b	14.42ab	16.44b	19.94b	13.56
NAA_I x $ASMDL_{65}$	7.46a	8.84b	13.81abc	15.72bc	18.97bc	12.96
NAA_I x $ASMDL_{50}$	5.93b	8.42b	12.01cd	15.37bc	18.62bc	12.07
NAA_0 x $ASMDL_{65}$	6.20b	8.29bc	12.92bcd	14.66bcd	17.91bcd	11.99
NAA_I x $ASMDL_{95}$	5.45b	8.12bc	12.53bcd	14.98bc	18.48bc	11.91
NAA_0 x $ASMDL_{50}$	5.10b	6.96c	11.46d	14.08cd	17.08cd	10.94
NAA_0 x $ASMDL_{95}$	4.94b	7.45bc	11.55cd	12.99d	15.99d	10.58
Tukey's value$_{0.05}$	**0.86**	**1.26**	**1.34**	**1.32**	**1.38**	

Means followed the same letter in a column do not differ significantly at 5% level of probability.

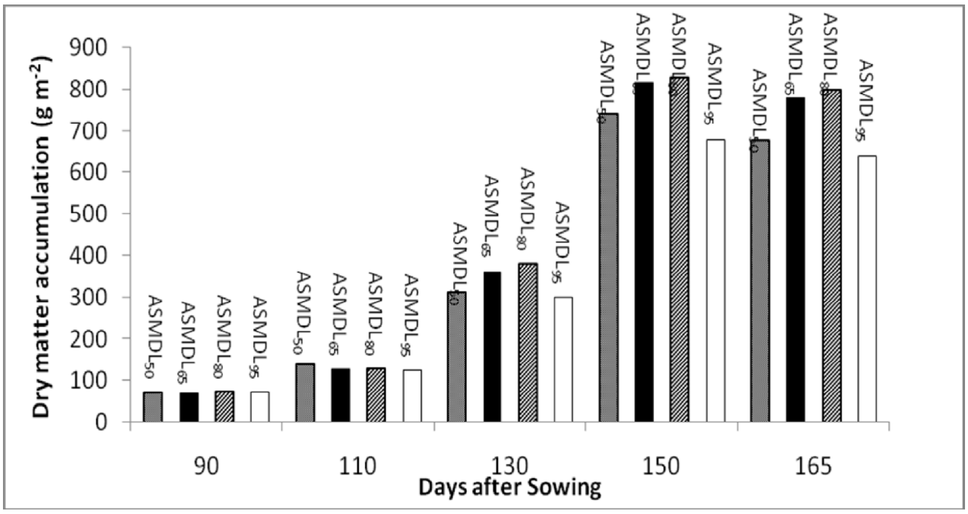

Fig.2.. Dry matter accumulation as affected by available soil moisture depletionlevels (3 years pooled data).

It was assessed that dry matter accumulation or crop growth rate decreased under water deficit as well as under excessive irrigation (16). It might be due to the reasons that moisture stress along with less nutrient availability decreased the rate of photosynthetic activities followed by flower shedding and hindering the fertilization. On the other hand over irrigation increased plant height (vegetative growth), causing impaired light penetration and air circulation resulting less pod setting (11). These findings were inline with those of Ghassemi-Golezani *et al.* (14) who concluded that water deficit decreased DMA and crop growth rate (CGR). It may be due to insufficient solvent for photosynthetic and metabolic activities.

Canopy development

Analysis of variance presented in Table 5 revealed significant differences between NAA and ASMDL for plant height, flower duration and pod bearing branches per plant. Treatment interaction of NAA and ASMDL had significant effects. The interaction between NAA and ASMDL was also significant for these canopy characters. Highest plant height of 72.88 cm was recorded in NAA_1× $ASMDL_{50}$ along with maximum flower duration of 63.50 days. While maximum pod bearing branches were recorded as 26.65 in NAA_1 and $ASMDL_{80}$. Plant height was decreased 2.14% where soil moisture was maintained at 95% without NAA spray with minimum flower duration of 52.25 days, which advocates that flowering was ceased due to water stress accompanied by less pod formation and hence the less yield. NAA application at flowering stage increased flower duration and pod bearing branches per plant by 10.97 and 9.25% respectively. It might be inferred that NAA might be used on chickpea for extention of flowering period and secondary branches per plant. Similarly maximum branches per plant were obtained where soil moisture was maintained at 80% depletion, thus giving an increase of 21% against 95% ASMDL which shows that plant remained under stress in either case of irrigation at 50% ASMDL or 95% ASMDL. Treatment combination of NAA_1 and $ASMDL_{80}$ depicted maximum branches per plant as 26.65 against minimum of 19.48 in $NAA_0\times ASMDL_{95}$. Branches per plant were decreased 26.9 and 10.77% under water stress ($NAA_0\times ASMDL_{95}$) and over irrigation ($NAA_0\times ASMDL_{50}$) respectively. It might be assessed that treatment combination of $NAA_1\times ASMDL_{80}$ are more reliable for better canopy development. The canopy management has a positive impact on yield by reducing lodging, improving light interception, air circulation along with efficient utilization of resources.

Yield and yield components

The interaction between NAA and ASMDL was also significant for all the parameters (Table 5). The treatment combination $NAA_1\times ASMDL_{80}$ showed highest (70.68) pods per plant. However, application of NAA remained on top with average 64.63 pods per plant. The treatment interaction for average number of seeds per pod and 100-seed weight (g) were ranging from 1.78 to 2.01and 26.11 to 30.15, which ultimately increased the grain yield ranging from 2535.3 to 3219.1 kg ha^{-1}. The increase in number of pods per plant, number of seeds per pod, 100-seeds weight and seed yield were 11.50, 6.99, 9.50 and 15.30% respectively with NAA and better than control (NAA_0). The ASMDL significantly increased the yield and yield components gaining maximum number of pods per plant (68.20), 100-seeds weight (28.98 g) and grain yield (3087.70 kg/ha) with 80% available soil moisture depletion level ($ASMDL_{80}$).

Plant growth regulator with optimum availability of soil moisture (20%) increased 26.35 and 23.76% number of pods per plant against $NAA_0\times ASMDL_{50}$ and $NAA_0\times ASMDL_{95}$, respectively (Table 5). This might be due to the reasons that NAA increased flowering and in turn pods per plant. The NAA application at 90 DAS increased pods per plant by 7.8%. Apart from this, over irrigation ($ASMDL_{50}$) and water stress ($ASMDL_{95}$) decreased number of pods per plant against $ASMDL_{80}$ by 15.23 and 12.71%, respectively. Moreover, over irrigation increased the plant height, chances of lodging, flower drop and less pod setting and drought stressed plants were unable to draw the solvent for the movement of solutes and the growth ceased. Hassan and Sarkar (16) observed that application of more than 143 mm irrigation water gradually decreased yield and water productivity, causing the wastage of irrigation water. Growth regulator (NAA) with 80% available soil moisture depletion level increased average number of seeds per pod (12.92%) Because, NAA enhanced the cell elongation with more flowers, reduced flower drop and helped in pod setting (1).

It is obvious that plant growth regulator showed an increase of 4.27% in number of seeds per pod compared with check. The average number of seeds per plant was increased (7.07%) by the availability of optimum water supply, i.e. $ASMDL_{80}$ against water stress conditions i.e.$ASMDL_{95}$.These results agree with those of Gan *et al*. (13), who concluded that seed yield was 8–19% more at 90% available moisture compared to 50 % available moisture. However, NAA increased hundred seeds weight over (8.46 %) control. An improvement of 7.53% in average 100 seed weight was recorded by optimum soil moisture supply ($ASMDL_{80}$) against over irrigation ($ASMDL_{50}$). These results revealed that NAA application alongwith maintenance of optimum soil moisture ($NAA_1 \times ASMDL_{80}$) in the root zone increased pods per plant (15.12%) against $NAA_0 \times ASMDL_{50}$. Application of NAA increased pods bearing capacity and other yield components like number of seeds per pod, 100-seed weight and ultimately the grain yield. Application of plant growth regulator with 80% ASMDL increased grain yield 26.97% compare with $NAA_0 \times ASMDL_{50}$. It might be NAA with optimum supply of soil moisture (ASMDL80) that increased number of pods per plant, seeds per pod, 100-seed weight and yield. Seed yield was increased by 10.26% with the application of plant growth regulator (NAA). It might be inferred that NAA encouraged flower retention and increased pods bearing branches, pods per plant, 100-grain weight and ultimately seed yield. These findings agree with those of Bai *et al*. (7) and Upadhyay *et al*. (25) who reported that spray of NAA enhanced the number of pods per plant, pod weight per plant and gave 17.7% higher seed yield over the control. It was observed that seed yield was decreased by 13.94% in $ASMDL_{50}$ and by 9.48% $ASMDL_{95}$ and maximum yield was recorded in $ASMDL_{80.}$ Thus irrigation water was saved by 27.42 % with better management.

Irrigation

It is depicted from three years pooled data that total supply of 252 mm irrigation water (Table 3) is optimum on sandy loam soil for maximum grain yield and dry matter accumulation (Fig. 2) under arid conditions. Water could be supplied in split doses with irrigation depth of 126 mm each. Thus irrigation water could be saved up to 22.22 % on sandy loam soil by irrigating the crop at 80% ASMDL against 50% ASMDL. It was observed that over irrigation ($ASMDL_{50}$) and under irrigation ($ASMDL_{95}$) decreased grain yield, resultantly wastage of precious water (16).

Water productivity (kg/mm)

The analysis of three year pooled data showed that maximum water productivity of 18.18 kg per ha per mm on sandy loam soil was recorded in the interaction of $NAA_1\times ASMDL_{95}$ and minimum water productivity of 8.23 kg/ha/mm with $NAA_0\times ASMDL_{50}$. It was observed that 54.73 percent water productivity was decreased on sandy loam soils, when ASMDL increased to $ASMDL_{50}$ without NAA.

Table 5. Effect of Naphthalene acetic acid and soil moisture depletion levels on yield, yield components and water use efficiency of chickpea (3 years pooled data).

Treatments	Levels	Plant height (cm)	Flower duration (days)	Pod bearing branches per plant	Pods/ plant	Grains/ pod	100 grain weight (g)	Grain yield (kg/ha)	Water productivity (kg/ha/mm)
NAA	NAA1	67.43a	60.69a	25.27a	64.63a	1.95a	29.10a	3013.0a	12.55a
	NAA0	63.13b	54.69b	22.93b	59.97b	1.87b	26.83b	2732.6b	11.35b
	Tukey's value $_{0.05}$	0.50	1.34	0.52	0.90	0.03	0.27	25.45	0.18
	Percent increase over NAA_0								
ASMDL	$ASMDL_{50}$	70.79a	61.25a	24.55b	57.81c	1.89ab	26.95c	2657.3d	8.63d
	ASMDL65	66.10b	56.38bc	25.10b	63.66b	1.97a	27.70b	2951.1b	9.77c
	ASMDL80	64.61c	58.13b	25.61a	68.20a	1.93ab	28.98a	3087.7a	12.25b
	ASMDL95	59.64d	55.00c	21.16c	59.53c	1.84b	28.23ab	2794.9c	17.15a
	Tukey's value $_{0.05}$	1.10	2.62	0.54	2.48	0.11	0.75	87.71	0.30
ASMDL × GR	NAAI x ASMDL80	67.30b	61.50ab	26.65a	70.68a	1.94ab	30.15a	3219.1a	12.77c
	NAAI x ASMDL65	68.45b	60.00ab	26.25a	66.23b	2.01a	29.30a	3090.4b	10.24e
	NAAI x ASMDL95	61.10d	57.75bc	22.85d	61.95c	1.91bc	29.25a	2963.2c	18.18a
	NAA0 x ASMDL80	61.93cd	54.75cd	24.58bc	65.73b	1.92bc	27.81b	2956.4c	11.73d
	NAAI x ASMDL50	72.88a	63.50a	25.33b	59.68cd	1.93ab	27.71b	2779.2d	9.02f
	NAA0 x $ASMDL_{65}$	63.68c	52.75d	23.88cd	61.10c	1.92bc	26.11c	2811.8d	9.31f
	NAA0 x $ASMDL_{95}$	58.20e	52.25d	19.48e	57.11de	1.78d	27.215bc	2626.7e	16.12b
	NAA0 x	68.70b	59.00abc	23.78cd	55.94e	1.85cd	26.190c	2535.3e	8.23g
	Tukey's value $_{0.05}$	1.86	4.54	1.24	2.99	0.05	0.90	84.50	0.51

Means followed the same letters in a column do not differ significantly at 5% level of probability.

Moreover, when irrigation water quantity was increased from $ASMDL_{95}$ to $ASMDL_{50}$, water productivity was decreased by 49.68 %. Treatment combination, $NAA_1 \times ASMDL_{80}$ gave the maximum yield of 3219.1 kg/ha with water productivity of 12.77 kg/ha/mm. Maximum water productivity was recorded when minimum irrigation level ($ASMDL_{95}$) was maintained (Table 5) and it decreased by 48.78 and 54.73 % with over irrigation (beyond the optimal dose) and no plant growth regulator. Application of irrigation at 50 % ASMDL kept the soil moist throughout the growth period creating suffocation in the rhizosphere and increased the chances of lodging due to which grain yield was decreased depicting less water productivity (8.63 kg ha^{-1} mm^{-1}). Similarly 95 % ASMDL created the drought conditions adversely affecting the growth. The results agree with earlier findings (8, 26, 13) who stated that water productivity increased as water application declined from maximum to optimum level.

Benefit cost ratio

Return of investment was calculated on the basis of benefit cost ratio (BCR). The analysis of three years pooled data regarding benefit cost ratio (BCR) (Table 6) revealed that different values of BCR were recorded at different ASMDL and growth regulator treatments.

Table 6. Three years average economic analysis and BCR as affected by naphthalene acetic acid and soil moisture depletion levels for chickpea (2007-08 to 2009-10).

Treatment	Seed yield (kg/ha)	Variables cost (Rs/ha)	Gross income (Rs/ha)	Total Cost (Rs/ha)	Net income (Rs/ha)	BCR
$NAA_0 \times ASMDL_{50}$	2535.3	500	56277	16169	39931	3.38
$NAA_0 \times ASMDL_{65}$	2811.8	400	62360	16169	42417	3.76
$NAA_0 \times ASMDL_{80}$	2956.4	300	65541	16169	45981	3.98
$NAA_0 \times ASMDL_{95}$	2626.7	200	58287	16169	40635	3.56
$NAA_1 \times ASMDL_{50}$	2779.2	700	61542	16169	46399	3.65
$NAA_1 \times ASMDL_{65}$	3090.4	600	68489	16169	51437	4.08
$NAA_1 \times ASMDL_{80}$	3219.1	500	71320	16169	54737	4.28
NAA_1 x $ASMDL_{95}$	2963.2	400	65690	16169	50359	3.96

Triple Super Phosphate (TSP) @ Rs. 950 per 50 kg during 2007, 1000 during 2008 and 1050 during 2009, Application charges of fertilizer/ha (1 man day) @ 100.00, Hand weeding @ Rs. 1000/ha (10 man days @ Rs. 100/day), Price of seed of Bittle-98 @ Rs. 19/kg during 2007, 22.50 during 2008 and 26 during 2009, Price of Inoculum Packet of 250 g/ha @ Rs. 100 per 250 g Packet., Application charges of Inoculum ha^{-1} (1/2 man day) @ Rs. 40.00, Income (straw) = Rs. 500/ha, Variables = Water application charges and Growth regulator charges

The highest BCR (4.28) was recorded in the interaction of $NAA_1 \times ASMDL_{80}$ and lowest (3.38) with $NAA_0 \times ASMDL_{50}$ on sandy loam soil. It was observed that 26.63 % higher BCR was recorded in the interaction of $NAA_1 \times ASMDL_{80}$ compared with $NAA_0 \times ASMDL_{50}$. The increase in BCR in the interaction of $NAA_1 \times ASMDL_{80}$ was ascribed to complimentary effects of increased nutrient availability and better photosynthetic activities with better utilization of resources resulting in higher grain yield and net benefit to the farmer.

CONCLUSION

From the foregoing discussions, it may be concluded that application of NAA with irrigation to chickpea crop at 80 % depletion of available soil moisture increased yield and yield components. Application of 252 mm irrigation water/ rainfall on sandy loam soil is economical under arid conditions with BCR of 4.28. Each irrigation depth must not be increased more than 126 mm to avoid the deep percolation. Therefore, irrigation at 80 % available soil moisture depletion level and application of NAA at 600 ml ha^{-1}, at flowering is best to obtain maximum grain yield of chickpea.

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