Indian Journal of Agronomy **60** (4): 576–580 (December 2015)

Research Paper

Effect of irrigation scheduling, conjunctive use of water sources and fertilizer levels on yield and water productivity of groundnut (*Arachis hypogaea*)

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Received : September 2014; Revised accepted : November 2015

ABSTRACT

A field experiment was conducted for 2 consecutive years 2008–09 and 2009–10 at Deras, Mendhasal, Odisha, to study the effect of conjunctive use of water sources and fertilizer levels on yield and water use of winter (*rabi*) season groundnut (*Arachis hypogaea L.*). The treatments included 3 levels of conjunctive use of water [C_1–(2 irrigations through canal water only, C_2–2 irrigations with canal water + 1 irrigation with ground water and C_3–2 irrigations with canal and 2 irrigations with ground water)] and 5 fertilizer treatments, [(F_0, no NPK; F_1, 100% NPK (20, 40 and 40 kg/ha as N, P_2O_5 and K_2O), F_2, sugarcane trash bio-compost (STBC) alone (1 t/ha); F_3, 75% NPK + sugarcane trash bio-compost (0.25 t/ha) and F_4, 50% NPK+ sugarcane trash bio-compost (0.50 t/ha)]. Pod and haulm yields of groundnut were significantly increased with conjunctive-use of water sources (ground and canal water) compared to canal water irrigation alone. The increase in pod yield was 45.3% and haulm yield 40.3% with conjunctive use of 2 irrigations through canal and 2 irrigations through ground water over 2 irrigations with canal water. This treatment also gave the maximum gross returns (₹47,714/ha), net returns (₹35,166/ha) and benefit: cost ratio (2.80). With application of 75% NPK + STBC (0.25 t/ha) 70.3% and 73.4% increase in pod and haulm yields was observed compared to the control (no fertilizer application). The highest water use (434 mm), water-use efficiency (5.06 kg/ha-mm) and benefit: cost ratio (3.11) were recorded with application of 75% NPK + STBC (0.25 t/ha).

Key words : Conjunctive use, Groundnut, Nutrient sources, Water sources, Water use, Water-use efficiency

Shortages of surface water supplies necessitate development of groundwater in many canal commands. When canal water supply is not available, the irrigation water availability can be improved by increasing ground water use in the winter (*rabi*) season. In minor irrigation canal commands, there is limited storage capacity of reservoir which permits only 2 irrigations in *rabi* season. For good yield of *rabi* groundnut crop there is requirement of 4 irrigations under humid tropical conditions of Odisha. Thus, supplementation of 1 or 2 irrigations through groundwater is necessary for optimum yield and economic return. For obtaining high economic returns per unit use of land and water, conjunctive water use planning could be more effective if ground water is utilized efficiently throughout the year in conjunction with canal/surface water sources (Sethi *et al*., 2006). Groundnut is one of the important oilseed crop of the world. In India among oilseed crops, groundnut occupies second position in terms of area (5.3 million ha) with a production of 7.0 million tonnes, which is nearly 23.5% of the country's total oilseed production (DES, 2012).

The yield of groundnut crop in general is higher during the winter (*rabi*) compared to the rainy (*kharif*) season. Hence, farmers prefer cultivation of *rabi* groundnut. The productivity of *rabi* groundnut was 1,938 kg/ha as compared to 1,188 kg/ha during *kharif* season (DES, 2012). The low productivity of *kharif* groundnut is mostly associated with rainfed conditions. Because of high productivity under assured irrigation, groundnut cultivation in *rabi* season is gaining popularity. Optimum scheduling of irrigation led to increase in pod yield and water use efficiency (Taha and Gulati, 2001). In eastern India, groundnut is widely grown in winter season *(rabi)* under irrigated and un-irrigated conditions on residual soil moisture with or without fertilizers. However, information on irrigation scheduling and fertilizer levels on *rabi* groundnut crop is

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scanty particularly with conjunctive water use scenario under shallow water-table conditions in coastal soils of Odisha. Therefore, the present experiment was conducted to investigate the effect of irrigation scheduling and fertilizer levels under surface and groundwater conjunctive use scenario.

MATERIALS AND METHODS

An experiment on groundnut was conducted for two consecutive years (2008–09 and 2009–10) at Deras, Mendhasal, Odisha in factorial randomized-block design. The soil is slightly acidic (*p*H 5.7), sandy clay-loam with low organic carbon content (0.46%). The treatments consisted of 3 levels of conjunctive water use [C_1–(2 irrigations through canal water only, C_2-2 irrigations with canal water + 1 irrigation with ground water and C_3–2 irrigations with canal and 2 irrigations with ground water)] and 5 fertilizer treatments. [F_0, no NPK; F_1, 100% RD of NPK; F_2, sugarcane trash bio-compost (STBC) alone (@ 1 t/ha); F_3, 75% RD of NPK + STBC (@ 0.25 t/ha); and F_4, 50% RD of NPK + STBC (@ 0.50 t/ha). The recommended fertilizer was applied @ 20, 40 and 40 kg/ha as N, P_2O_5 and K_2O, respectively. N was supplied through urea, P_2O_5 through DAP and K_2O through muriate of potash. 'Smurti' variety of groundnut was sown on first week of December 2008 and 2009, respectively. The crop was harvested on 20 April, 2009 and 24 April, 2010. In *rabi* season, the irrigation schedules were followed at critical crop-growth stages of groundnut crop. Two irrigations of canal water were applied during branching (25 days after sowing (DAS) and pod formation stages (70 DAS) of groundnut crop in C_1 treatment. Two irrigations of canal water and 1 irrigation of groundwater applied in C_2 treatment during branching (25 DAS), pegging (45 DAS) and pod formation stages (70 DAS), respectively. While, 2 irrigations of canal water and 2 irrigations of groundwater were applied in C_3 treatment during branching (25 DAS), pegging (45 DAS), pod formation (70 DAS) and pod filling stages (85 DAS), respectively. Conjunctive use planning was done using canal water and ground water source (Table 1). The total amount of rainfall received during the groundnut cropping season was 0 mm and 12 mm in 2008–09 and 2009–10, respectively. The total quantity of water applied to crop was 140 mm, 190 mm and 240 mm, respectively in C_1, C_2 and C_3 conjunctive water use treatments. Soil samples were collected plot wise at different soil depths at periodic intervals for soil moisture analysis. The moisture contribution from soil profile was estimated 188 mm, 180 mm and 175 mm, respectively. The consumptive-water use (CWU) by the crop was computed from the depletion of soil water storage in the root zone as per the following water balance equation:

$$CWU = \sum_{t1}^{t2} \Delta S \Delta t + (R + I) - DP$$

Where, CWU is the consumptive-water use in mm, ΔS is the change in soil moisture storage in the root zone in mm, R is the rainfall in mm, I is the irrigation applied in mm, DP is the deep percolation loss in mm, t_1 and t_2 are the start and end of growing season. Gravimetric moisture content was determined after oven drying the samples at 105°C for 24 hours.

Crop water use efficiency (kg/ha/mm) was computed using following formula.

$$WUE = \frac{\text{Pod yield (kg/ha)}}{\text{Consumptive water use (mm)}}$$

For working out the economics, prevailing market prices for pod yield (₹21,000/tonnes), haulm yield (₹2,000/tonnes), urea (₹10.90/kg N), SSP (₹21.90/kg P) and MOP (₹7.70/kg) were considered. The data were statistically analysed and the pooled results are presented.

RESULTS AND DISCUSSION

Yield attributes

The yield attributes of groundnut were significantly influenced with conjunctive use of water sources and fertilizer levels (Table 2). Conjunctive use of 2:2 irrigations through canal and ground water sources gave more number of pods/plant (13.3), shelling percentage (68.1%), 100-pod weight (76.7 g) and 100 kernel weight (52.2 g) com-

Table 1. Conjunctive use planning for irrigating the groundnut crop

Conjunctive use treatment	Irrigation depth (cm)	Amount of total water applied (m^3) in 18 m^2 area	Share of water sources (%)		Amount of total water applied (m^3/ha)	
			CW	GW	CW	GW
2 irrigations of CW	7 + 7	2.52	100%		1400	–
2 CW + 1 GW	7 + 7 +5	2.52+0.90	73.7%	26.3%	1400	500
2 CW + 2GW	7+7+5+5	2.52+1.80	58.3%	41.7%	1400	1000

CW, Canal water; GW, groundwater

pared to 2 irrigations through canal and 1 irrigation through groundwater C_2 and canal water (2 irrigations only). The fertilizer application was also significantly influenced the yield attributes of groundnut with conjunctive use of irrigation water from different sources (Table 2). These results are in close conformity with findings of Hosamani and Janavade (2007) and Zagade and Chavan (2009). Application of 75% of NPK in combination with 25% N through sugarcane trash bio-compost and 100% NPK produced higher number of pods/plant (13.10 and 12.92), shelling percentage (69% and 68%) and improved weight of 100-pods (77.34 g and 76.70 g) and kernels (53.3 g and 52.2 g) over the control. Patra and Sinha (2012) reported higher yield attributes of groundnut with organic fertilization

Pod and haulm yields

The conjunctive-use of water sources significantly influenced the pod and haulm yields of groundnut crop. Results revealed that both for pod and haulm yields, treatments C_2 and C_3 were significantly superior than C_1. However, C_2 and C_3 were statistically at par (Table 2). The irrigation water availability for groundnut crop was improved by 1 and 2 irrigations through groundwater in addition to 2 irrigations through canal water. The pod-yield (9.6% and 45.3%) and haulm yield (10.6% and 40.3%) increased with 2 irrigations each with ground and surface water (conjunctive use of 2:2 irrigations through canal and ground water sources) compared to 2 irrigations through canal and 1 irrigation through groundwater (C_3) and canal water (2 irrigations only). It might be due to better soil moisture availability in soil profile. Regarding fertilizer treatments, the highest yield was recorded with F_3 (75% NPK + sugarcane trash bio-compost), and the lowest in control. The application of 100% NPK alone and 75% NPK + sugarcane trash biocompost treatments were statistically similar for both pod and haulm yields (Table 2). Application of 75% NPK + sugarcane trash bio-compost application enhanced pod and haulm yields by 70.3% and 73.4% compared to control. With supplemental irrigation, increase in pod yield was reported by Reddy and Sulochanamma (2008). Shinde *et al*. (2000) found that the application of 75% recommended dose of fertilizer resulted in higher productivity of groundnut at Rahuri in Maharashtra. Hosamani and Janavade (2007) reported that crop receiving 4 irrigations of 6 cm depth, each scheduled at critical stages (pre-flowering, pegging, pod formation and pod filling stages) and *dhaincha* green manuring along with recommended dose of fertilizer (25 : 75 : 25 kg/ha, N, P_2O_5, K_2O) recorded significantly higher pod yield. Groundnut under polythene mulch supplemented with groundwater irrigation at 0.6, 1.0 and 0.8 IW: CPE ratio resulted in higher yields of dry pod, haulm and kernel, respectively (Zagade and Chavan, 2009). Patra and Sinha (2012) reported higher pod and haulm yields with organic fertilizer application.

Water-use by groundnut

The crop water use efficiency was influenced by conjunctive use levels (Table 3). The crop water use efficiency

Table 2. Yield attributes, pod and haulm yields of groundnut as influenced by conjunctive-use of water sources and fertilizer levels (pooled data of 2 years)

Treatment	Pods/plant	Shelling (%)	100-pod weight (g)	100 kernel weight (g)	Pod yield (t/ha)	Haulm yield (t/ha)
Conjunctive use level						
C_1	10.2	65.6	73.3	48.1	1.37	2.11
C_2	12.8	67.1	75.7	50.8	1.82	2.68
C_3	13.3	68.1	76.7	52.2	1.99	2.96
SEm±	0.21	0.41	0.47	0.75	0.74	0.17
CD (P=0.05)	0.66	1.2	1.4	2.22	2.21	0.52
Fertilizer level						
F_0	10.9	64.5	72.7	46.9	1.29	1.90
F_1	12.9	68.1	76.7	52.2	2.04	3.06
F_2	11.3	65.1	73.6	47.9	1.37	2.06
F_3	13.1	68.9	77.3	53.3	2.19	3.29
F_4	12.2	67.4	75.8	51.1	1.74	2.67
SEm±	0.33	0.77	0.83	1.07	0.94	1.02
CD (P=0.05)	0.98	2.3	2.5	3.24	2.80	3.01

C_1–2 irrigations through canal water only; C_2–2 irrigations with canal water + 1 irrigation with ground water; C_3–2 irrigations with canal water + 2 irrigations with ground water; F_0, no NPK; F_1, 100% RD of NPK; F_2, sugarcane trash bio-compost alone (@ 1 t/ha), F_3, 75% RD of NPK + sugarcane trash bio-compost (@ 0.25 t/ha) and F_4, 50% RD of NPK + sugarcane trash bio-compost (@ 0.50 t/ha)

(WUE) (4.84 kg ha/-mm) was slightly higher with application of 3 irrigations (2 irrigations through canal and 1 supplementary irrigations through groundwater source) compared to C_3 (2 CW irrigations + 2 GW supplementary irrigations). The lowest WUE was observed with C_1 (2 irrigations only through canal water source). The various fertilizer levels also influenced the water use and WUE of groundnut crop. The highest water use was observed with 75% NPK fertilizes + sugarcane trash bio-compost application (434 mm), which was higher than other fertilizer treatments. Application of 75% NPK fertilizers along with sugarcane trash bio-compost recorded maximum WUE (5.06 kg/ha-mm) followed by 100% NPK fertilizers alone (4.95 kg/ha-mm). The lowest WUE (3.94 kg/ha-mm) was observed with no fertilizer application (control). Application of 75% of NPK fertilizers in combination with 25% N through sugarcane trash bio-compost implying efficient use of irrigation water under different conjunctive use treatments. Higher WUE was recorded with 4 irrigations (pre-flowering, pegging, pod formation and pod filling stages), compared to 3 irrigations (flowering, pod formation and pod filling stages) reported by Hosamani and Janavade (2007).

Economics

The conjunctive use of different water sources significantly increased the economic variables of groundnut. The gross and net returns were influenced significantly due to different irrigation water sources in terms of quantity of irrigation water applied to groundnut. Maximum gross (₹47,714/ha) and net returns (₹35,166/ha) were recorded with two irrigations supplemented through groundwater in addition to two canal water irrigations, which was 44.6% and 57.8% higher than only 2 canal water irrigations (Table 3). These results are supported by Rasker *et al*. (2009). Among the fertilizers levels, application of 75% NPK + 25% N through sugarcane trash bio-compost gave the highest gross and net returns of ₹52,658 and ₹39,837/ha with benefit: cost ratio of 3.11. Canal water irrigations (2 irrigations) alone was not sufficient to increase the pod yield and economic returns of groundnut crop, that is why two irrigations were supplemented through ground water resulted in increase in pod yield and ultimately in economic returns. Therefore, irrigation scheduling through conjunction of 2 canal water irrigations with 2 groundwater irrigations was best in terms of economic benefit under humid tropical conditions of Odisha.

It could be concluded that irrigation water availability for groundnut crop was improved by 1 and 2 irrigations supplemented through groundwater in addition to 2 irrigations through canal water. The conjunctive use combination of 2: 2 (canal and groundwater irrigations) enhanced pod yield by 45.0% over 2 irrigations of canal water source. This treatment also gave the maximum gross (₹47,714/ha), and net returns (₹35,166/ha) and benefit: cost ratio (2.80). Application of 75% NPK+ sugarcane trash bio-compost enhanced pod yield by 70% and 7.6% compared to the control and 100% NPK (20–40–40 kg N,

Table 3. Consumptive use, water use efficiency and economics of groundnut as influenced by conjunctive use of water sources and fertilizer levels (pooled data of 2 years)

Treatment	Water-use (mm)	Water-use efficiency (kg/ha-mm)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Conjunctive use level					
C_1	334	4.10	33.0	22.3	2.11
C_2	376	4.84	43.5	31.6	2.64
C_3	421	4.73	47.7	35.2	2.80
SEm±		0.06	1.8	1.34	0.04
CD (P=0.05)		0.19	5.35	4.05	0.13
Fertilizer level					
F_0	327	3.94	30.8	20.7	2.03
F_1	412	4.95	48.9	35.3	2.59
F_2	343	3.99	32.8	22.3	2.13
F_3	434	5.06	52.7	39.8	3.11
F_4	369	4.70	41.7	30.5	2.74
SEm±		0.11	2.49	2.08	0.05
CD (P=0.05)		0.32	7.46	6.25	0.15

C_1–2 irrigations through canal water only, C_2–2 irrigations with canal water + 1 irrigation with ground water, C_3–2 irrigations with canal water + 2 irrigations with ground water; F_0-–no NPK; F_1–100% RD of NPK; F_2–sugarcane trash bio-compost alone (@ 1 t/ha), F_3–75% RD of NPK + sugarcane trash bio-compost (@ 0.25 t/ha) and F_4-50% RD of NPK+ sugarcane trash bio-compost (@ 0.50 t/ha)

P_2O_5 and K_2O/ha). Maximum WUE (5.06 kg/ha-mm) with benefit: cost ratio of 3.11 was recorded with application of 75% NPK fertilizers + sugarcane trash bio-compost.

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