International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 691-698

Received: 15-09-2019
Accepted: 19-10-2019

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Effect of irrigation regimes on the growth, yield and water use efficiency under groundnut based intercropping system: A review

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Abstract
Irrigation management nowadays need to be properly monitored to cope with depleting fresh water resources and enhance agricultural productivity. Groundnut a major oilseed crops of India accounts to 25% of total oilseed production in the country. India's vegetable oil requirement by 2022 is estimated 33.2 million tonnes and currently imports about 70% of the requirement accounting about 73,000 crores per annum. Further, industrialization and urbanization has led to decreased land availability and are preferring to cultivate cash crops like cotton, maize, etc. This along with pulses shortage has led to malnutrition in young children which needs to be addressed shortly. This review outlines on performance of groundnut under different irrigation frequencies and evaluates intercrops like castor, blackgram, sesame and pearlmillet and their performances with groundnut. From the review collected it could be studied that groundnut responds to different irrigation frequencies and also performs well under intercropping system but with certain short duration crops. Irrigation can be supplied more frequent at 10-15 days interval during summer and 15-20 days interval during winter and more compatible with blackgram followed by sesame, castor and pearlmillet. This could be primarily due to the lesser shading effect caused by the companion short duration crop and also atmospheric nitrogen fixation in case of legumes while negative effect when intercropped with exhaustive crops. Therefore, proper irrigation scheduling needs to be quantified along with best suited intercrop to enhance the productivity and profitability from the system.

Keywords: Irrigation scheduling, groundnut, intercropping, castor, blackgram, sesame, pearlmillet

Introduction

Groundnut (*Arachis hypogaea* L.) is an annual legume belongs to the family Fabaceae originated from South America. It is one of the principal foods and oilseed crops of tropical and sub-tropical regions of the world. It is commonly called as poor man's almond (or) wonder nut. It is the world's fourth most important source of edible oil and third most excellent source of vegetable protein to both human and animals. Moreover, it is also an important traditional cash crop for peasants in poor tropical countries (Shiyam, 2010) [75].

Groundnut is the major oilseed of India accounting 25% of the total oilseed production of the country with yearly production of 6.73 million tonnes. In India, it occupies an area of 4.59 m ha, with an average productivity of 1465 kg ha-1. In Tamil Nadu it occupies an area of 0.34 m ha with an average productivity of 2753 kg ha-1 (Chauhan *et al.*, 2016) [9].

Groundnut not only tastes good, but, is also rich in protein, fat and various healthy nutrients. The fat content ranges from 44-56% mainly containing mono and poly unsaturated fatty acids like oleic acid (40-50%) and linoleic acid (24-35%). In addition, it also fairly rich in calcium, iron and vitamin B complex like thiamine, riboflavin, niacin and vitamin A (Baraker *et al.*, 2017) [5]. Groundnut is said to be a risky crop under dryland conditions and only 19% of groundnut area in India is under irrigation. The productivity is largely determined on the availability of rainfall received during the stage of gynophore formation and initial pod development. Soil moisture stress at this critical stage may lead to severe yield reductions resulting in heavy loss to the farmer. Aberrant weather conditions have led to an imbalance in the edible oil production due to decreased productivity. This has led to economic losses to the farmers due to the partial or total failure of groundnut crop discouraging the farmers from urbanization has decreased the potential of increasing the area under oilseed and pulse crops.

Therefore, introduction of groundnut in intercropping system offers a better scope for maximizing and stabilizing the return from oilseed crops rather than as sole (Uddin *et al.*,

2003) [84]. Groundnut cultivation under intercropping system is mostly by small and marginal farmers with traditional combinations involving 5 to 6 crops.

Crop diversification could be adopted as a strategy in employment generation throughout the year and also maximizing the profit through reaping the gains by equating the substitution and price ratios for competitive products (Deshpande *et al.,* 2007) [17]. Crop compatibility is the most essential factor for a practicable intercropping system. Intercropping provides scope for improving the productivity and monetary return per unit area per unit time (Annadurai and Uthayakumar, 2010) [1].

The success of any intercropping system relies on the appropriate selection of companion crop where, competition between them for radiation, CO2 nutrients, moisture, spaces etc., is minimized (Willey and Reddy, 1981) [90]. Usually partner crops belonging to the same family or types or growth durations are competitive for natural resources whereas the crops of different categories, such as cereals and legumes, are generally complementary in nature thus, mutually benefited (Keating and Carberry, 1993) [30].

Land has become a limiting factor due to rapid industrialization and urbanization creating an inequality amid demand and supply of edible oil due to lower production of oilseed crops. Further, the shortage of pulses along with edible oils has also aggravated the problem of malnutrition. This can be achieved by increasing the productivity from the existing area by adopting appropriate agronomic practices, of which intercropping system can be depended as one of the best ways to increase productivity from unit available land (Chaudhari *et al.,* 2017) [8].

The intercropping system is an essential possibility which not only aims at increasing productivity at a particular time, but also insurances against total crop failure under aberrant weather conditions. The yield advantages in intercropping systems are coupled with complete utilization of environmental resources over time and space (Natarajan and Willey, 1986) [44]. Groundnut can be well intercropped with sorghum, pigeon pea, sunflower, cotton, castor and tapioca in various agro-ecological situations (Reddy and Suresh, 2009) [66]. But, the data available on the groundnut based intercropping system and its performance under different irrigated condition is inadequate due to insufficient research work.

Water is one of the vital inputs in farming and its availability is tending to become ever more scare and costlier due to increased industrialization, intensive agriculture and climate change. Water supply will be the major natural resource constraint, restraining economic development and food grain production in India. Hence, conservation of water and its efficient use has alleged much significance at recent times. The foremost prospect for increasing efficiency of water use at farm level lies in identifying the crop water requirement throughout its growth.

Under irrigated situation, plants extract water from field capacity to permanent wilting point. This phenomenon can be regulated by proper irrigation scheduling in such a way that it does not compensate with the yield of the crop. Irrigation scheduling differs from crop to crop whose identification helps in saving water while maintaining the soil moisture level. Effective utilization of available water resources is crucial for countries like India which share about 17% of the global population with only 2.4% of land.

Agriculture is largest user of water, consuming more than 80% of the country's exploitable water resources. It is estimated that the allocation is to be reduced to 71% in the next two decades. Development of appropriate water management technologies to maximize the crop productivity per drop of water is the need of the hour (Kumar *et al.,* 2017) [33]. Increased water uses efficiency (WUE) of crops can be possible through appropriate irrigation scheduling by providing only the water that match the crop evapotranspiration and irrigating at critical growth stages (Deng *et al.,* 2006) [14].

Regulated irrigation under intercropping system are very promising when the optimum irrigation scheduling is identified for the crop at particular agro-climatic zone. Irrigation schedules can be classified as full and deficit irrigation, on basis of plant, soil, and climatic conditions (Fabeiro *et al.,* 2002) [19]. Proper irrigation scheduling provides means of reducing water wastage through evaporation with increased yields (Molden *et al.,* 2010) [41]. Intercropping system is generally more productive than sole crop (Ijoyah *et al.,* 2013) [24] and also, could be a way of saving irrigation water (Walker *et al.,* 2005) [89].

Therefore, the present research was undertaken to study the effect of different irrigation regimes on the growth and yield of groundnut and its water use efficiency under intercropping system.

Effect of Water Deficit on Crop Performance

The important factor affecting growth and yield of a crop is the moisture stress during the cropping season. Therefore, a need for strategies that maximize the efficiency of water use from the limited amounts of water utilized for crop growth.

Climate, agronomic and varietal factors mainly determine total water use by a crop. At vegetative phase of growth, soil moisture deficit increases the total biomass accumulation along with higher pod yield. The increase could possibly be due to increase in total leaf area at reproduction resulting in higher partitioning to the reproductive parts. Further, the yield advantage from water stress at vegetative stage significantly increases the synchrony in flower formation eventually increasing the peg to pod conversion.

Plant height is a product of the number of nodes and internodal length in groundnut. Soil water deficits at vegetative stage in groundnut significantly induced reduction in internodal length more drastically than the number of nodes (Ochs and Wormer, 1959) [46] although rate of node increase was decreased. The stem morphology was also altered by water deficit. Groundnut significantly responded producing increased stem elongation when the quantity of water applied was correspondingly equal to that lost in either open pan evaporation (Desai *et al.,* 1985) [15] or by evaluating crop evapo-transpiration (Reddy, 1988) [67].

Lopez *et al.* (1996) [38] stated that the rate of leaf area expansion, leaf area duration and LAI were gradually reduced with intensified soil water deficits. Alteration of leaf morphology also resulted in water stress. Constant soil water deficit induced fewer and smaller leaves which had smaller and more compactness of cells (Lin *et al.,* 1963) [36] and higher specific leaf weight. The xeromorphic structure of leaf was retained even after sufficient water application, although newer leaf development was noticed apparently static.

Dry matter accumulations in groundnut could be attributed to the growth of leaf and stem at vegetative phase and also to the pod and kernel growth combination simultaneous with shift in leaf and stem biomass at reproductive phase. Shelke and Khuspe (1980) [73] reported that water stress at flowering and pod development stages significantly decreased dry matter.

Total dry matter accumulation and dry weight remained unchanged by mild stress during vegetative period (Sivakumar and Sarma, 1985; Reddy *et al.*, 1996) [69] Higher pod to shoot ratio along with petite periodic water stress was noted by Boote (1982) [7]. In groundnut, reproductive growth consists of three distinct stages viz., flower production; pegs development which pushes the ovary below ground; pod filling stage (Wright and Rao, 1994) [91]. At flowering, moderate soil water deficit has delayed by 1 to 2 days simultaneously reducing the number of flowers (Lenka and Misra, 1973) [35].

Billaz and Ochs (1961) [6] stated that water stress during 50-80 days after sowing (DAS) on a short season groundnut crop subsequently decreased formation of flower and pegs and produced a greater yield decline than moisture stress at different growth stages. This reduction in flowering in due course resulted in reduced photosynthate supply, reduction in turgor and also low relative humidity. Low relative humidity often accompanies with water deficit reducing the rate of flowering (Ong *et al.*, 1985) [47]. From this it could be attributed that flowering is most sternly affected by water deficits (Su *et al.*, 1964) [82]. Soil moisture stress at stages of pegging, pod initiation considerably reduced the number of pods per plant but pod weight is not much effected (Rao *et al.*, 1984; Wright and Rao, 1994) [91, 58]. Soil water content in the top soil 1 to 2 cm is very crucial for peg entrance into the soil as they fail to penetrate efficiently into air dry soil reducing pod growth (Sivakumar and Sarma, 1985) [77].

Stern (1968) [81] and Sivakumar and Sarma (1985) [77] also reported that pod growth continues only after full pod expansion which is affected by insufficient surface moisture. Inadequate water in the pod zone also known to depress calcium uptake causing more pops (unfilled pods) and lesser double locule pod (Skelton and Shear, 1971; Cox *et al.*, 1976) [78, 12]. Likewise, quite a lot of researchers have stated that enough water supply significantly improved total filled pods per plant (Katre *et al.*, 1988; Lakshmi, 1990) [29, 34].

Pod filling or kernel development stages have been noticed to decrease 100 kernel weight by 22 percent (Varnell *et al.*, 1975; Pathak *et al.*, 1988) [86, 52]. and per pod weight (Underwood *et al.*, 1971; Lenka and Misra, 1973) [85, 35]. Similarly, Yao *et al.* (1982) noted 100 kernel weight decreased by 24.7, 25.1 and 14.7 percent as a result of water deficits respectively at flowering, pod filling and ripening periods. Many reports from conducted research outline a significant increase in 100 kernel weight by regulating optimum water during kernel or pod filling stages (Ramachandrappa and Kulkami, 1992; Reddy *et al.*, 1996) [55, 69].

In groundnut, the shelling percentage or sound mature kernel was noted to be decreased under water deficit conditions (Stansell *et al.*, 1976; Boote, 1982) [80, 7]. Water stress beginning from 36 to 70 DAS and after 71 to 105 DAS further decreased in mature pods plant-1 and also decreased the shelling percentage up to 73.4 and 69.7 percent on comparison to 76.5 percent under irrigated check (Stansell and Pallas Jr, 1985) [79]. Although, 35-day water stress at late pod filling stage (105 to 140 DAS) increased shelling percentage as the stress at later stages eliminated the addition of younger immature pod (Stansell and Pallas Jr, 1985) [79]. Similarly, reduction in shelling percentage noted 28 percent under pod filling stage on comparison to irrigated control plot (Pathak *et al.*, 1988) [52].

Excess application of irrigation promotes vegetative growth which is at the expense of reproductive growth (Sivakumar and Sarma, 1985) [77]. Vivekanandan and Gunasena (1976) [88] stated that increased soil water potential shown to cause higher LAI along with excessive vegetative growth, but decrease in pod yield was noticed and was also indicated by lower harvest index. The timing and severity of water deficit influenced the harvest index in harmony to fruit set. While, moderate water stress from the sowing to the beginning of peg initiation (0 to 51 DAS) was noted to have no effect on biomass production, but noted to improve yield by 12 to 19 percent. The harvest index of 0.5 was recorded for full irrigated groundnuts, while as high as 0.57 harvest index under stress condition at 0 to 51 DAS, and as low as 0.24 for long-standing water deficit at pod filling stages. Water deficit during pod formation stage (50 to 80 DAS) was shown to cause momentous reduction in harvest index (Billaz and Ochs, 1961; Reddy and Reddy, 1993) [6, 68]. Studies on the quality parameters of groundnut exposed an increase in oil content resultant of an increase in availability of soil moisture availability to the crop (Saini and Sandhu, 1973; Rasve *et al.*, 1983) [70, 62] while Sharma and Singh (1987) [72] reported no considerable effect due to frequent supply of soil moisture on the oil content of groundnut. Although, water deficits at kernel growth or pod filling period shown to reduce the oil content. Similarly, Wright and Rao (1994) [91] noted that imposition of early water stress from emergence to peg initiation improved oil content, but when stress was enforced from flowering to initiation of kernel growth reduced the oil content.

Therefore, to efficiently supply irrigation to groundnut, one should understand the phase of crop growth and development. For an instance, the depth of water extraction is primarily prejudiced by rooting pattern, crop density and canopy which influences the crop evapotranspiration leading to increased water uptake from the soil. Furthermore, stages like pegging and pod formation also studied to have additional water requirement. Finally, irrigation should be applied as life irrigation to make certain of germination and emergence and to relieve tremendous stress at non-availability of irrigation water to the crop to outperform (Wright and Rao, 1994; Puangbut *et al.*, 2010) [58, 54].

Scheduling of Irrigation through Climatological Approach

The climatological approach, which is of recent origin, is based on the knowledge that water use by crops is primarily controlled by the evaporative demand of the climate, provided, there is adequate moisture supply, ground cover and crop is at active growth. Climatological approach focuses to irrigate the crops via IW/CPE ratio (Parihar, 1974) [49].

A. Groundnut

Maintenance of sufficient available soil moisture in the root zone should coincide with critical growth stages of crop for proper water uptake as well as utilization of soil nutrients. It creates a favourable impact on growth as well as yield components directing towards better pod yield in groundnut crop. Several researches have reported the increasing yield of groundnut crop with successive increase in the moisture regimes directing towards better performance of crop indicating the response of groundnut to applied irrigation (Geethalakshmi and Lourduraj, 1998; Nautiyal *et al.*, 2002; Ramakrishna *et al.*, 2006) [21, 45, 56].

Pahalwan and Tripathi (1984) [48] noticed that scheduling of irrigation at lower frequency i.e. either at 0.5 or 0.7 ratio from planting to flowering followed by 0.9 ratio during pegging to pod formation or 0.7 and 0.9 ratio during pod formation to maturity had little or no effect on pod yield as compared to the treatment which was maintained at 0.9 IW/CPE ratio throughout the crop growth. Patel *et al.* (2008) [50] indicated that irrigation regime at 40mm Cumulative Pan Evaporation (CPE) recorded significantly higher pod yield over 50mm and 60mm CPE. Further suggested that, consumptive use increased with decrease in IW/CPE and attributed to better growth and higher yield of crop with lesser wastage of water applied.

Rathod and Trivedi (2011) [63] recorded the higher pod yield of 3082 kg per ha under IW/CPE of 0.9. It was noticed that the pod yield increased with increasing rate from IW/CPE of 0.6 to 0.9. The optimal water requirements were observed to be 757mm in order to maximize pod yield to 2927 kg per ha. Further, the pooled data of three years exhibited that fodder yield increased with increase in the level of water application at IW/CPE of 0.6 to 1.2. While, the maximum fodder yield of 6640 kg per ha was possible with optimal water input of 1011mm. Arunkumar *et al.* (2017) [3] indicated that application of irrigation to groundnut and other intercrops with irrigation level 0.7 IW/CPE was significantly superior over IW/CPE 0.6, IW/CPE 0.5 and IW/CPE 0.4 and were on par.

Naresha *et al.* (2017) [43] reported that yield attributes viz., number of pods per plant, 100 kernel weight (g), shelling percentage were considerably inclined by different moisture regimes and recorded higher at 1.0 IW/CPE and was on par with 0.8 IW/CPE for number of pods per plant, 100 kernel weight (g), shelling percentage. The higher pod and haulm yields (21.5 and 38.4 q ha-1) were recorded under irrigation regime at 1.0 IW/CPE, which was on par with 0.8 IW/CPE while lower values were recorded in 0.6 IW/CPE.

Lokhande *et al.* (2018) [37] noticed that the dry pod, haulm, kernel, oil, biological yields and bio-energy of summer groundnut were significantly higher under irrigation scheduled at 1.0 IW/CPE on par with 0.8 IW/CPE.

B. Castor

Firake *et al.* (1998) [20] reported that maintenance of favourable soil moisture content under 0.8 IW/CPE aided the crop to accumulate higher dry matter (36.4 g plant-1) comparable to 0.2 (26.6 g plant-1), 0.4 (30 g plant-1) and 0.6 (32.9 g plant-1) IW/CPE ratio. Further a linear increase in bean yield of castor was noticed with increasing IW/CPE ratio from 0.2 to 0.8 at rabi season. Experimental trial conducted at Bhavanisagar, Tamil Nadu shown that irrigating TMV 5 castor at 0.6 IW/CPE was better than irrigating at 0.4 and 0.8 IW/CPE level of irrigation (Selvaraj, 1992) [71]. Koutroubas *et al.* (2000) [32] stated that bean yield of castor under irrigated condition was significantly higher than under rainfed condition and further elucidated that irrigation of castor with water equivalent to 75 percent of soil moisture depletion was adequate to attain maximized bean yield. Nagabhushanam (2002) [42] recorded higher growth and yield parameters under IW/CPE ratio of 0.8 on comparison with 0.4 and 0.6 IW/CPE ratio irrigated at 15 days interval. On the other hand, Ravi Kumar (2010) [65] indicated that the castor crop in 0.8 IW/CPE irrigation schedule recorded 24.5 percent more plant height in comparison over the rainfed crop which stipulated the response of castor towards irrigation. Leaf area index between 0.6 and 0.8 IW/CPE was similar and significantly superior to 0.4 IW/CPE ratio due to maintenance of higher soil water regime through adequate water supply at 0.8 IW/CPE ratio favoured optimum LAI (Ramanjaneyulu *et al.*, 2013) [57]. Further, Arunkumar *et al.* (2017) [3] registered castor yield in castor intercropping system ranging from 1898 kg ha-1 in 0.5 IW/CPE ratio to 2588 kg ha-1 in 0.7 IW/CPE ratio.

C. Blackgram

Vijayalakshmi and Rajagopal (1995) [87] carried out an experimental trial at Water Technology Center, Tamil Nadu Agricultural University, Coimbatore to evaluate the effect of different irrigation level on yield attributes and yield of greengram (*Vigna radiata* L.) and indicated irrigation at IW/CPE 0.60 significantly increased the pods per plant, seeds per pod and 100 seed weight which eventually reflected on the yield of the crop. Chettri *et al.* (2004) [10] conducted a field experiment during summer season at Mohanpur (W.B.) to study the response of summer blackgram (*Phaseolus mungo* L.) to irrigation scheduling and recorded higher dry matter accumulation, number of pods per plant with higher number of seeds per pod, 1000 seed weight and seed yield (9.3 q per ha-1) when irrigated at early pod filling stage.

Patel *et al.* (2008) [50] conducted a field trial on summer blackgram during at Navsari Agricultural University (Gujarat) and noted that water use efficiency (WUE) was higher under irrigation at 0.9 IW/CPE ratio and water expense efficiency was higher under irrigation at 0.5 IW/CPE.

Experiment trial conducted at Indian Agricultural Research Institute, New Delhi by Idnani and Singh (2008) [23] during summer season, 2004 and 2005 with two irrigation regimes (I1 - two Irrigation in which one each at pre-flowering and pod filling stages and I2 - three irrigation one each at branching, pre flowering and pod filling stages) of whose results indicated that three irrigations (I2) recorded significantly higher plant height, LAI, total nodules, effective nodules, nodule dry weight and total dry weight in comparison over two irrigations (I1) applied at respective stages. Patel and Patel (2009) [51] observed that irrigation regime at 0.8 IW/CPE ratio significantly improved the yield of chick pea (1156 kg ha-1) respectively, as compared to irrigation schedule with IW/CPE ratio 1.0, 0.6 and 0.4.

Shirgapure and Fathima (2018) [74] revealed that scheduling irrigation with 80 percent CPE resulted in higher increase of growth parameters viz., plant height, leaf area and dry matter production at harvest in all pulses viz., greengram (27.39, 9.39 and 33.86 percent, respectively), blackgram (32.44, 30.41 and 36.32 percent, respectively) and fieldbean (23.48, 20.47 and 30.68 percent, respectively) over recommended irrigation practice.

D. Sesame

Parihar (1974) [49] and Rao *et al.* (1991) [60] noted that irrigation regime at IW/CPE ratio of 0.9 was sufficient for sesame cultivation during summer season.

Arunachalam and Venkatesan (1984) [2] evaluated an experiment in the sandy loam soils of Tamil Nadu and reported that sesame (CO 2) when irrigated, either at IW/CPE 0.30 or 0.45 IW/CPE ratio during vegetative and reproductive phases (3 to 4 irrigations of 50 mm depth) produced every time higher seed yield (714 kg ha-1) in all the consecutive years (1979-80 to1981-82). Rao *et al.* (1991) [60] reported that delaying (0.60 IW/CPE ratio) or narrowing the irrigation interval (1.2 IW/CPE ratio) the seed, oil and biomass yields were subsequently reduced. Further, noticed that irrigation scheduling at 0.6 IW/CPE was found to be optimum, with slight increase in yield over irrigation at 0.8 IW/CPE.

Shrivastava and Tripathi (1992) [76] observed that Irrigation scheduling at IW/CPE 0.7 to sesame crop during summer season recorded significantly higher seed yield and yield attributes over irrigation schedules at IW/CPE 0.5 level of irrigation. Further, noticed that frequent irrigations at IW/CPE 0.9 did not confirm significantly higher over irrigation at IW/CPE 0.7 in producing higher yields.

Rao and Raikhelkar (1993) [59] evaluated irrigation scheduling with three IW/CPE ratios i.e. 0.6, 0.9 and 1.2., the IW/CPE 0.9 registered significantly higher CGR values of sesame throughout the crop growth while the other IW/CPE ratios were on par with each other.

Dutta *et al.* (2000) [18] reported an increase of all growth attributes and yield components with increase in number of irrigations from 1 to 3. Further, three irrigations one each applied at branching, flowering and capsule development stages registered higher yield (seed + oil) of sesame followed by 2 irrigations (branching and flowering).

E. Pearlmillet

Kachhadiya *et al.* (2010) [26] reported that plant height was increased considerably by irrigating the crop at 1.0 IW/CPE over 0.6 IW/CPE at 30, 45, 60 DAS and at harvest, and the increase was to the tune of 7.4, 11.9, 11.3 and 4.8 percent, respectively. The leaf area index noted at 30, 60 DAS and at harvest increased with increase in irrigation levels from 0.6 to 1.0 IW/CPE ratio. Similarly, various yield attributes viz., number of effective and non-effective tillers per plant, length and girth of ear head, grain weight per plant and test weight registered under irrigation levels 1.0 and 0.8 IW/CPE did not differ significantly but resulted higher over 0.6 IW/CPE treatment.

Khafi *et al.* (2011) [31] revealed that grain and fodder yield of pearlmillet were significantly affected by different depths of irrigation at different irrigation intervals. Application of irrigation at 40 mm depth resulted in more grain and fodder yield over 60mm by 25 percent and 21 percent, respectively.

Raval *et al.* (2015) [64] reported that irrigation scheduling at 1.2 IW/CPE ratio gave significantly higher plant height (160.02 cm), number of tillers (71.24) and leaf: stem ratio (1.78), green forage yield (119.23 t ha-1), dry matter yield (28.83 t ha-1) and per day productivity (9.23 q ha-1) over the other levels of irrigation. However, maximum WUE (86.07 kg ha-1) was recorded under 0.8 IW/CPE ratio of irrigation. Green forage and dry matter yield improved significantly with increase in the level of irrigation up to 1.2 IW/CPE ratio with higher yield potential of 75.45 and 121.55 percent respectively, over irrigation scheduling at 0.6 IW/CPE.

Thakor *et al.* (2018) [83] reported that irrigation schedule at 0.8 IW/CPE ratio recorded significantly higher growth and yield attributing characters viz., plant height, LAI, number of effective tillers, length and girth of ear head, grain weight per head and test weight as well as grain and straw yields of summer pearl millet, but it remained statistically at par with 1.0 IW/CPE ratio. It was interesting to note that treatment 0.8 IW/CPE ratio increased in grain yield by 28.96 and 6.73 percent over treatment 0.6 and 1.0 IW/CPE ratios respectively. Similarly, increase in straw yield under 0.8 IW/CPE by 27.80 and 6.41 percent respectively.

Water use efficiency

Water use efficiency (WUE) is a measure of attainable pod yield per hectare per unit depth of water supplied indicating whether irrigation schedule followed was successful in conserving water, but it does not define the point of higher economic yield. Increased WUE occurred in less irrigated treatment but were prone to less economic yields. Water deficits at vegetative stage subsequently increased the WUE of groundnut as a result of higher water saving at the cost of crop yields (Patil and Gangavane, 1990; Reddy and Reddy, 1993) [90, 68]. The seasonal water use (Eta) in groundnut is controlled by climatic factors, agronomic factors and varietal factors. In groundnut, daily Eta of improved Virginia bunch averaged 6.9 mm day-1 from 53 to 83 DAS (Mantell and Goldin, 1964) [39]. Ishag *et al.* (1985) [25] in the Virginia bunch type recorded peak Eta rates of 7 to 8 mm day-1 from 75 to 85 days.

Kassam and Stockinger (1973) [28] stated that peak ET happened shortly before peak LAI was noticed. Subsequent to full foliage development and ground cover, daily ET steadily declined until the plants attained maturity. This decline could be a consequence of plant senescence (loss in LAI and leaf conductance) and to seasonal cut in evaporative demand. The crop coefficients were reported to increase linearly from 0.3 to 1.0 percent to the rise in ground cover from 0 to 100 percent which significantly increases the LAI during the growth of groundnut (Yayock and Owonubi, 1985) [93]. Further, Dancette and Forest (1986) also acknowledged that crop coefficient for short season groundnut pointed slightly above 1.0 between 50 to 70 DAS of crop growth.

Pahalwan and Tripathi (1984) [48] conducted an experiment at Hyderabad (India) and revealed that the maximum pod yield (20.5 q ha-1) was recorded in the continuous 0.9 IW/CPE ratio. However, the higher water use efficiency (39.5 kg ha-1 cm-1) was obtained in the continuous 0.8 IW/CPE levels of irrigation. Ramachandrappa and Kulkami (1992) [55] noted higher WUE of 83.91 kg ha-1 mm-1 when irrigations were scheduled at an IW/CPE 0.5 from 10-70 DAS followed by IW/CPE 0.75 from 70 days to harvest of groundnut in sandy loam soil of Bangalore during summer season. Similarly, WUE was recorded higher (7.44 and 7.09 kg ha-1 mm-1) by scheduling irrigations at 50 percent depletion of soil moisture level or 50 mm CPE (Babalad and Kulkarni, 1993) [4].

Metochis (1993) [40] reported that daily Eta rates under optimum soil moisture conditions greater than before from 1.5 to 2.0 mm per day at the beginning of growing season followed by 7.0 to 7.5 mm per day during full crop development stages but, decreased to 2 to 3.0 mm per day at the later stages of growth. It is evident from the study that the Eta/ETo ratio was increased by more frequent irrigations (Goldberg *et al.*, 1971; Karunasagar and Narsa Reddy, 1998) [22, 27]. The seasonal pattern in ET of groundnut could be related to the canopy development pattern and higher of LAI.

WUE decreased with the increased number of irrigations or increased WUE can be realised through decreased consumptive water use. Water requirement was increased with an increase in the level of irrigation, however, mean maximum WUE was recorded with lower moisture regimes (Deshpande, 1999; Raskar and Bhoi, 2003; Chitodkar *et al.*, 2005) [16, 61, 11]. Patel *et al.* (2008) [50] reported that WUE increased with decrease in irrigation interval where the mean highest WUE (4.76 kg ha-1 mm-1) was attained with 40 mm CPE while the least was with 60 mm CPE. Arunkumar *et al.* (2017) [3] observed that the mean data on groundnut equivalent yield (kg ha-1) and WUE (kg ha-1 mm-1) showed that the 0.7 IW/CPE recorded significantly higher value compared to other treatments. In terms of intercropping system, the groundnut equivalent yield and WUE was higher (11.34) under groundnut + maize but it was par with groundnut + redgram (11.15). While, least groundnut equivalent yield WUE was registered with sole crop of groundnut.

Conclusion

In India, nearly 80% of fresh water is utilized for irrigation and depleting ground water source is prime factor in decreasing the agricultural productivity. Resources such as suitable land, nutrients and most importantly irrigation water, remain a scarce. Sustainable utilization of these natural resources can only be achieved better through supplying only adequate quantity of irrigation water and properly studying the compatibility of intercrops. Steps need to be taken in order to increase the farmers adoption level for newer technologies to enhance productivity and profitability from a particular enterprise.

References

1. Annadurai K, Uthayakumar R. Controlling setup cost in (Q, r, L) inventory model with defective items. Applied Mathematical Modelling. 2010; 34(6):1418-1427.
2. Arunachalam L, Venkatesan G. Effect of bio-fertilizer application on the yield of sesamum. Madras Agricultural Journal. 1984; 71(4):259-260.
3. Arunkumar P, Maragatham N, Panneerselvam S, Ramanathan S, Jeyakumar P. Water requirement of groundnut under different intercropping system and WUE in groundnut equivalent rate. The Pharma Innovation Journal. 2017; 6(11):322-325.
4. Babalad H, Kulkarni G. Economisation of Irrigation Water and Soil Moisture Depletion Pattern in Summer Groundnut. Journal Maharashtra Agricultural Universities. 1993; 18:109-109.
5. Baraker B, Jha S, Wani S. Effect of improved management practices on economics in Groundnut (*Arachis hypogaea* L.) cultivation. International Journal of Chemical Studies. 2017; 5(4):302-304.
6. Billaz R, Ochs R. Stades de sensibilité de l'arachide à la sécheresse. Oleagineux. 1961; 16(10):605-611.
7. Boote K. Growth stages of peanut (*Arachis hypogaea* L.). Peanut Science. 1982; 9(1):35-40.
8. Chaudhari D, Vekariya P, Vora V, Talpada M, Sutaria G. Enhancing productivity of groundnut based intercropping systems under rainfed conditions of Gujarat. Legume Research. 2017; 40(3):520-525.
9. Chauhan J, Prasad SR, Pal S, Choudhury P, Bhaskar KU. Seed production of field crops in India: Quality assurance, status, impact and way forward. Indian Journal of Agricultural Sciences. 2016; 86(5):563-579.
10. Chettri M, Mondal S, Konar A. Integrated nutrient management for enhancing productivity and sustaining soil fertility under potato (*Solanum tuberosum*)-based cropping system in West Bengal. Indian Journal of Agricultural Science. 2004; 74(4):210-212.
11. Chitodkar S, Bhoi P, Patil H, Pawar P. Effect of irrigation regimes, mulches and antitranspirant on yield and yield contributing characters of summer groundnut. Journal of Maharashtra Agricultural Universities. 2005; 30(2):230-232.
12. Cox F, Sullivan G, Martin C. Effect of calcium and irrigation treatments on peanut yield, grade and seed quality. Peanut Science. 1976; 3(2):81-85.
13. Dancette C, Forest F. Water requirements of groundnuts in the semi-arid tropics. Agrometeorology of Groundnut, Andhra Pradesh, India, 1986.
14. Deng XP, Shan L, Zhang H, Turner N. Improving agricultural water use efficiency in arid and semiarid areas of China. Agricultural Water Management. 2006; 80(1-3):23-40.
15. Desai N, Joshi R, Patel K. Effect of irrigation on growth and yield attributes of summer groundnut. Agricultural Science Digest. 1985; 5(1):63-66.
16. Deshpande M. Response of summer groundnut (*Arachis hypogaea* L.) genotypes to different irrigation levels. M. Sc. (Agri.) Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, 1999.
17. Deshpande R, Mehta P, Shah K. Crop diversification and agricultural labour in India. Indian Journal of Labour Economics. 2007; 50(4):597-610.
18. Dutta D, Jana P, Bandyopadhyay P, Maitry D. Response of summer sesame (*Sesamum indicum* L.) to irrigation. Indian Journal of Agronomy. 2000; 45(3):613-616.
19. Fabeiro C, de Santa Olalla F, De Juan J. Production of muskmelon (*Cucumis melo* L.) under controlled deficit irrigation in a semi-arid climate. Agricultural Water Management. 2002; 54(2):93-105.
20. Firake N, Shinde S, Magar S. Drip irrigation scheduling for castor in sandy clay loam. Journal Maharashtra Agricultural Universities. 1998; 23(3):280-282.
21. Geethalakshmi V, Lourduraj A. Effect of gypsum application on yield and economics of groundnut. Legume Research. 1998; 21(1):13-16.
22. Goldberg S, Rinot M, Karu N. Effect of trickle irrigation intervals on distribution and utilization of soil moisture in a vineyard. Journal of Soil Science Society of America. 1971; 35(1):127-130.
23. Idnani L, Singh R. Effect of irrigation regimes, planting and irrigation methods and arbuscular mycorrhizae on productivity, nutrient uptake and water use in summer greengram (*Vigna radiata* L.). Indian Journal of Agricultural Sciences. 2008; 78(1):53-57.
24. Ijoyah M, Ogar A, Ojo G. Soybean-maize intercropping on yield and system productivity in Makurdi, Central Nigeria. Scientific Journal of Crop Science. 2013; 2(4):49-55.
25. Ishag H, Fadl O, Adam H, Osman A. Growth and water relations of groundnuts (*Arachis hypogaea* L.) in two contrasting years in the irrigated Gezira. Experimental Agriculture. 1985; 21(4):403-408.
26. Kachhadiya S, Chovatia P, Jadav K, Sanandia S. Effect of irrigation, mulches and antitranspirant on yield, quality and economics of summer pearlmillet. International Journal of Agricultural Sciences. 2010; 6(1):278-282.
27. Karunasagar G, Narsa Reddy S. Moisture-use pattern of a groundnut (*Arachis hypogaea* L.) based intercropping system in semi-arid environment. Indian journal of agricultural science. 1998; 68(1):171-173.
28. Kassam A, Stockinger K. Growth and nitrogen uptake of sorghum and millet under mixed cropping. Samaru Agricultural News. 1973; 15:89-91.
29. Katre R, Chandrakar B, Bajpai R, Sahu K, Choudhary K. Effect of irrigation and phosphorus on pod yield of summer groundnut. Journal of Oilseeds Research. 1988; 5(1):59-65.
30. Keating B, Carberry P. Resource capture and use in intercropping: solar radiation. Field Crops Research. 1993; 34(3-4):273-301.
31. Khafi H, Mehta AC, Bunsa B, Dangaria C, Davda B. Response of summer pearl millet (*Pennisetum glaucum* L.) to irrigation scheduling. Crop Research. 2011; 41(3):28-30.
32. Koutroubas S, Papakosta D, Doitsinis A. Water requirements for castor oil crop (*Ricinus communis* L.) in

a Mediterranean climate. Journal of Agronomy and Crop Science. 2000; 184(1):33-41.
33. Kumar V, Sharma A, Soni JK, Pawar N. Physiological response of C3, C4 and CAM plants in changeable climate. The Pharma Innovation. 2017; 6(9):70.
34. Lakshmi MB. Studies on irrigation and phosphorus management in groundnut-maize cropping sequence. Agronomy, ANGRAU, 1990.
35. Lenka D, Misra P. Response of groundnut (*Arachis hypogaea* L.) to irrigation. Indian Journal of Agronomy, 1973, 492-497.
36. Lin H, Chen C, Lin C-Y. Study of drought resistance in the Virginia and Spanish types of peanut. Journal of the Agricultural Association of China. 1963; 43(1):50-51.
37. Lokhande D, Jayewar N, Mundhe A. Summer groundnut (*Arachis hypogaea* L.) productivity influenced by irrigation scheduling: A climatological approach. International Journal of Current Microbiology and Applied Sciences SI. 2018; (6):87-91.
38. Lopez F, Johansen C, Chauhan Y. Effects of timing of drought stress on phenology, yield and yield components of short-duration pigeonpea. Journal of Agronomy and Crop science. 1996; 177(5):311-320.
39. Mantell A, Goldin E. Influence of irrigation frequency and intensity on the yield and quality of peanuts. Israel Journal of Agricultural Research. 1964; 14:203-210.
40. Metochis C. Irrigation of groundnut (*Arachis hypogaea* L.) grown in a Mediterranean environment. The Journal of Agricultural Science. 1993; 121(3):343-346.
41. Molden D, Oweis T, Steduto P, Bindraban P, Hanjra MA, Kijne J. Improving agricultural water productivity: Between optimism and caution. Agricultural Water Management. 2010; 97(4):528-535.
42. Nagabhushanam U. Performance of castor hybrid in relation to seeding dates and irrigation schedules in rabi season. Agronomy, ANGRAU, 2002.
43. Naresha R, Laxminarayana P, Devi KS, Narender J. Effect off moisture regimes and phospho-gypsum levels on yield, nutrient uptake and soil nutrient balance of rabi groundnut. International Journal of Agriculture, Environment and Biotechnology. 2017; 10(4):489-498.
44. Natarajan M, Willey R. The effects of water stress on yield advantages of intercropping systems. Field Crops Research. 1986; 13(1):117-131.
45. Nautiyal P, Rachaputi NR, Joshi Y. Moisture-deficit-induced changes in leaf-water content, leaf carbon exchange rate and biomass production in groundnut cultivars differing in specific leaf area. Field Crops Research. 2002; 74(1):67-79.
46. Ochs R, Wormer T. Influence de l'alimentation en eau sur la croissance de l'arachide. Oleagineux. 1959; 14(5):281-291.
47. Ong C, Black C, Saffell R. Influence of Saturation Deficit on Leaf Production and Expafision in Stands of Groundnut (*Arachis hypogaea* L.) Grown Without Irrigation. Annals of Botany. 1985; 56(4):523-536.
48. Pahalwan D, Tripathi R. Irrigation scheduling based on evaporation and crop water requirement for summer peanuts. Peanut Science. 1984; 11(1):4-6.
49. Parihar S. Scheduling irrigations to wheat, using pan evaporation. Indian Journal of Agricultural Science. 1974; 44:567-571.
50. Patel G, Patel P, Patel P. Yield, water use efficiency and moisture extraction pattern of summer groundnut as influenced by irrigation schedules, sulfur levels and sources. Journal of SAT Agricultural Research (Open Access journal published by ICRISAT). 2008; 6:1-4.
51. Patel J, Patel Z. Effect of different level of irrigation, rhizobium inoculation and nitrogen on content and uptake of nitrogen in chickpea. Indian Journal of Agricultural Sciences (India). 2009; 47(2):47-56.
52. Pathak S, Patel M, Qureshi A, Ghodasara G. Effect of water stress on yield and diurnal changes of biophysical parameters of groundnut. Legume Research. 1988; 11(4):193-195.
53. Patil B, Gangavane S. Effects of water stress imposed at various growth stages on yield of groundnut and sunflower. Journal of Maharashtra Agricultural Universities. 1990; 15(3):322-324.
54. Puangbut D, Jogloy S, Toomsan B, Vorasoot N, Akkasaeng C, Kesmala T. *et al* Drought stress: Physiological basis for genotypic variation in tolerance to and recovery from pre-flowering drought in peanut. Journal of Agronomy and Crop Science. 2010; 196 (5):358-367.
55. Ramachandrappa B, Kulkami K. Pod yield, total water use, consumptive use, water use efficiency and moisture extraction pattern of summer groundnut as influenced by irrigation schedules. Journal of Oilseeds Research. 1992; 9 (1):51-51.
56. Ramakrishna A, Tam HM, Wani SP, Long TD. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Research. 2006; 95(2-3):115-125.
57. Ramanjaneyulu A, Reddy AV, Madhavi A. The impact of sowing date and irrigation regime on castor (*Ricinus communis* L.) seed yield, oil quality characteristics and fatty acid composition during post rainy season in South India. Industrial crops and products. 2013; 44:25-31.
58. Rao I, Bubu M, Reddy P. Effect of phosphorus and Rhizobium on groundnut. Andhra Agricultural Journal (India). 1984; 31(3):253-254.
59. Rao P, Raikhelkar S. Effect of irrigation and fertilization on growth and yield in sesame. Journal of Oilseeds Research. 1993; 10:31-31.
60. Rao V, Raikhelkar S, Sondge V. Sequential growth and yield-component analysis of sesame (*Sesamum indicum* L.). Indian Journal of Agricultural Sciences. 1991; 61(5):303-307.
61. Raskar B, Bhoi P. Response of summer groundnut (*Arachis hypogaea* L.) to irrigation regimes and mulching. Indian Journal of Agronomy. 2003; 48 (3):210-213.
62. Rasve S, Bharambe P, Ghonsikar C. Effects of irrigation frequency and method of cultivation on yield and quality of summer groundnut. Journal of Maharashtra Agricultural Universities. 1983; 8(1):57-59.
63. Rathod A, Trivedi S. Summer groundnut crop performance and economics under drip irrigation at various water application levels. National Conference on Recent Trends in Engineering and Technology, 2011.
64. Raval C, Patel A, Bhatt P, Vyas K, Bedse R, Patel C, Patel S. Response of multi-cut summer forage pearl millet (*Pennisetum glaucum*) to varying levels of irrigation and nitrogen under semi-arid condition of north Gujarat. Forage Research. 2015; 41(1):34-39.
65. Ravi Kumar B. Irrigation management in drip irrigated castor (*Ricinus communis* L.). Agronomy, Acharya NG Ranga Agricultural University, 2010.

66. Reddy B, Suresh G. Crop diversification with oilseed crops for maximizing productivity, profitability and resource conservation. Indian Journal of Agronomy. 2009; 54(2):206.
67. Reddy CR. Studies on yield response to water in groundnut (*Arachis hypogaea* L.). Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad, 1988.
68. Reddy CR, Reddy SR. Scheduling irrigation for peanuts with variable amounts of available water. Agricultural Water Management. 1993; 23(1):1-9.
69. Reddy P, Reddy B, Rao VP, Sarma P. Effect of water deficits at different crop growth periods on growth and yield of groundnut. Journal of Research APAU. 1996; 24:147-149.
70. Saini J, Sandhu R. Yield and quality of groundnut as affected by irrigation and fertilizer levels. Journal of Research, Punjab Agricultural University. 1973; 10 (2):179-183.
71. Selvaraj R. Effect on castor as influenced by different irrigation regimes. Indian Journal of Agronomy. 1992; 23(2):37-43.
72. Sharma K, Singh G. Effect of water stress on yield and quality of groundnut. Environment and Ecology. 1987; 5 (1):647-650.
73. Shelke D, Khuspe V. Pattern of dry-matter accumulation and uptake of phosphorus by Latur No. 33 groundnut as influenced by different levels of irrigation, phosphorus and antitranspirant during summer. Indian Journal of Agronomy. 1980; 25(3):362-369.
74. Shirgapure K, Fathima P. Growth and yield of pulses as influenced by irrigation levels in southern dry zone of Karnataka. Journal of Pharmacognosy and Phytochemistry. 2018; 7(1):2444-2448.
75. Shiyam JO. Growth and yield response of groundnut (*Arachis hypogaea* L.) to plant densities and phosphorus on an ultisol in Southeastern Nigeria. Libyan Agriculture Research Center Journal International. 2010; 1(4):211-214.
76. Shrivastava G, Tripathi R. Effect of irrigation, mulch and nitrogen levels on growth and yield of summer sesame (*Sesamum indicum*). Indian Soc Agronomy Indian Agr Res Inst Div Agronomy, New Delhi 110012, India, 1992.
77. Sivakumar M, Sarma P. Studies on water relations of groundnut. Agrometerology of groundnut. Proceedings of International Symposium ICRISAT Sahelian centre Niamey, Niger, 1985.
78. Skelton BJ, Shear G. Calcium translocation in the peanut (*Arachis hypogaea* L.). Agronomy Journal. 1971; 63(3):409-412.
79. Stansell J, Pallas Jr J. Yield and quality response of Florunner peanut to applied drought at several growth stages. Peanut Science. 1985; 12(2):64-70.
80. Stansell J, Shepherd J, Pallas J, Bruce R, Minton N, Bell D *et al* Peanut responses to soil water variables in the Southeast. Peanut Science. 1976; 3(1):44-48.
81. Stern W. The influence of sowing date on the yield of peanuts in a short summer rainfall environment. Australian Journal of Experimental Agriculture. 1968; 8(34):594-598.
82. Su KC, Chen T, Hsu SC, Tseng M. Studies on the processing of water absorption and economized irrigation of peanuts. Journal of Agricultural Association of China. 1964; 41:43-51.
83. Thakor K, Usadadia V, Savani N, Arvadia L, Parth BP. Effect of irrigation schedule and nitrogen management on productivity, profitability of summer pearl millet grown under clay soils of south Gujarat. International Journal of Agriculture Innovations and Research. 2018; 6 (4):2319-1473.
84. Uddin MS, Rahaman M, Bagun S, Uddin M, Rahman M. Performance of intercropping of maize with groundnut in saline area under rainfed condition. Pakistan Journal of Biological Sciences. 2003; 6(2):92-94.
85. Underwood C, Taylor H, Hoveland C. Soil physical factors affecting peanut pod development. Agronomy Journal. 1971; 63(6):953-954.
86. Varnell, R, Mwandemere H, Robertson W, Boote K. Peanut yields affected by soil water, no-till and gypsum. Soil and Crop Science Society of Florida 1975; 35(1):56-59.
87. Vijayalakshmi R, Rajagopal A. Effects of irrigation levels and irrigation layouts on the yield attributes and grain yield of green gram. Madras Agricultural Journal. 1995; 82:271-273.
88. Vivekanandan A, Gunasena H. Lysimetric studies on the effect of soil moisture tension on the growth and yield of maize (*Zea mays* L.) and groundnut (*Arachis hypogaea* L.). Beitrage zur Tropischen Landwirtschaft und Veterinärmedizin. 1976; 1(1):369-378.
89. Walker S, Tsubo M, Hensley M. Quantifying risk for water harvesting under semi-arid conditions: Part II. Crop yield simulation. Agricultural Water Management. 2005; 76(2):94-107.
90. Willey R, Reddy M. A field technique for separating above-and below-ground interactions in intercropping: an experiment with pearl millet/groundnut. Experimental Agriculture. 1981; 17(3):257-264.
91. Wright G, Rao RN. Groundnut water relations. In The Groundnut Crop. 1994; 281-335. Springer.
92. Yao J, Luo Y, Yang X. Preliminary report on the effects of drought on seed development and quality of early groundnut. Chinese Oil Crops Zhongguo Youliao. 1982; 3:50-52.
93. Yayock J, Owonubi J. Weather-sensitive agricultural operations in groundnut production: the Nigerian situation. Agrometeorology of Groundnut. 1985; 213(1):213-226.