Effect of Moisture Regimes on Water use Efficiency of Rabi / Summer Groundnut Genotypes in Northern Transition Zone of Karnataka

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ABSTRACT

Background: During rabi / summer irrigation water is a scarce resource, but crop needs more water due to non-rainy season and warmer climate. Hence, a field experiment was conducted during rabi / summer season of 2016-17 to study the effect of irrigation water regimes on water use efficiency (WUE) of groundnut genotypes in Northern Transition Zone of Karnataka.

Methods: This field study comprised of four main plots as water regimes viz. I1: (control) seven irrigations at 15 days interval from sowing to 105 DAS, I2: Stress at pegging stage; withdrawal of one irrigation between 45 - 60 DAS, I3: Stress at pegging and pod filling stage; withdrawal of two irrigations between 45-75 DAS, I4: Stress at pegging, pod filling and kernel development stage; withdrawal of four irrigations from 45-105 DAS and four genotypes as sub plots viz. G1: Dh-86, G2: Dh-101, G3: K-9 and G4: G-52. Treatments were replicated thrice and laid out in split plot design.

Result: Among the water regime, I2 recorded significantly higher WUE (6.2 kg ha^{-1} mm^{-1}) followed by I1 (control; 5.5 kg ha^{-1} mm^{-1}). Water regime I4 also recorded significantly higher pod yield and haulm yield (2,857 kg ha^{-1}, 4,648 kg ha^{-1}, respectively) along with other yield attributes, but was found at par with control (I1). This study showed that WUE as well as yield of rabi / summer groundnut can be enhanced if crop was exposed only to mild stress by skipping an irrigation at pegging stage out of total seven irrigations. Among the genotypes, Dh-86 with 2,375 kg ha^{-1} of pod yield performed significantly better over others like Dh-101 (2,215 kg ha^{-1}), K-9 (2,048 kg ha^{-1}) and G-52 (1,880kg ha^{-1}) suggesting differential response to moisture stress, thus choice of moisture stress tolerant genotypes is equally important to enhance WUE. Interaction between irrigation regime and genotypes showed that Dh-86 (G1) with I2 irrigation regime recorded significantly higher WUE (6.9 kg ha^{-1} mm^{-1}), pod yield (3,168 kg ha^{-1}) and net return (Rs. 95,655 ha^{-1}) and was found at par with full irrigation regime (I1).

Key words: Groundnut, Moisture stress, Water regime, WUE, Pod yield.

INTRODUCTION

Groundnut (Arachis hypogaea L.) is an oilseed crop grown in almost all the tropical and sub-tropical countries of the world. Developing countries in the semi-arid tropics (SATs) together contribute 50 per cent of global production of which only India and China have 30 and 20 per cent share to make up half the share. In India, groundnut alone accounts for 45 per cent of the total oilseed area and 60 per cent of the total oilseed production and is cultivated in all the three seasons viz., rainy (85 %), post-rainy (10 %) and summer (5 %). In India, it is grown in 27 states on an area of 4.88 million ha with a production of 9.25 million tonnes and with an average productivity of 1893 kg ha^{-1} (Anonymous 2019). In Karnataka, groundnut is grown on area of 5.80 lakh hectares with a production of 4.23 lakh tonnes with the productivity of 729 kg ha^{-1} (Anonymous 2019).

The productivity of Karnataka is very low compared to national average as most of the area is under rainfed and being an unpredictable legume, shows inconsistency in pod and oil yields. Further, it has been proved that water is most critical input that affects crop growth and yield and its scarcity leads to great reduction in productivity of groundnut especially during rabi/summer season. Research efforts need to be strengthened to narrow down the existing yield gap by management practices (e.g., irrigation) and selection of suitable genotypes to enhance yield. To sustainably alleviate the moisture deficit effects and improve groundnut production, it is imperative to identify suitable cultivars. The varieties should be able to provide higher yield and water use efficiency under moisture stress situation. In this context, an experiment was conducted to study the effect of moisture regimes on yield and yield attributes, economics and water use efficiency of groundnut genotypes for Northern Transition Zone of Karnataka.
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**MATERIALS AND METHODS**

A field experiment was conducted during rabi / summer (December to April) 2016-17 at AICRP on groundnut UAS, Dharwad located at 15°26’ North latitude, 75°07’ East longitude and at an altitude of 678 m above mean sea level (MSL). It lies under the Northern Transition Zone (Zone-8; NTZ) of agro-climatic zones of Karnataka on medium deep black soil. The experiment was laid out in split plot design with three replications involving four water regimes viz. I:\*, Control : i.e., seven irrigations at 15 days interval from sowing to 105 days after sowing (DAS), I:\*, Stress at pegging stage by withdrawal of one irrigation at 45-60 DAS, I:\*, Stress at pegging and pod filling stage with withdrawal of two irrigations at 45-75 DAS, I:\*, Stress at pegging, pod filling and kernel development stage i.e., withdrawal of four irrigations from 45-105 DAS as main plots and four genotypes as sub plots viz. G1: Dh-86, G2: Dh-101, G3: K-9 and G4: G2-52. The soil of the experimental site was medium black clay with pH (7.43), EC (0.21 dS m\(^{-1}\)), organic carbon content was (0.56 %), available N (249 kg ha\(^{-1}\)), P\(_2\)O\(_5\) (23 kg ha\(^{-1}\)) and K\(_2\)O (359 kg ha\(^{-1}\)). The mean monthly rainfall from September to April for the past 66 years at the Main Agricultural Research Station, Dharwad was 351.4 mm, whereas the rainfall received during September - April 2016 was 127.4, which was much lower than long-term average. Total number of pods produced plant\(^{-1}\) was counted in all the five plants and average per plant was worked out. The developed pods were dried completely (up to 8 % moisture level) and weighed. On the basis of pod yield for net plot, the pod yield ha\(^{-1}\) was calculated. After plucking the pods from harvested groundnut plants, the remaining produce was sun dried to constant weight and haulm yield plot\(^{-1}\) was recorded. From each plot, 200 g of clean pods were weighed and kernels were obtained after shelling. Shelling per cent was worked out by dividing kernel weight by pod weight and expressed in percentage. After shelling the pods, 100 kernels were randomly taken and weighed. To workout the cost of cultivation, the price of the inputs that were prevailing at the time of use was considered and expressed in rupees per hectare (’ ha\(^{-1}\)). The price of the crop products prevailing in the market after the harvest was used for the calculation of gross returns (’ ha\(^{-1}\)). The net returns per hectare was calculated by deducting the cost of cultivation from the gross returns and expressed in rupees per hectare (’ ha\(^{-1}\)). The water use efficiency was calculated by dividing crop yield by total amount water used in the field and expressed as kg/ha-mm. The analysis and interpretation of data were studied using the Fischer’s method of analysis of variance technique as described by Gomez and Gomez (1984).

**RESULTS AND DISCUSSION**

Effect of moisture stress on yield and yield attributes of groundnut genotypes

The pod yield depends on yield components which in turn depends upon the growth and yield attributes. The practical way of judging the efficacy of the treatments in any agronomic experiment is by comparing the yield variations. Moisture stress at different growth stages of crop had a significant influence on yield and yield attributes. Stress at pegging stage (I\(_1\)) recorded higher pod yield and haulm yield (2,857 kg ha\(^{-1}\), 4,658 kg ha\(^{-1}\), respectively) and other yield attributes. However, it was at par with I\(_1\) (water regime) no moisture stress crop (2,869 kg ha\(^{-1}\), and 4691 kg ha\(^{-1}\)). The higher pod yield and haulm yield in I\(_1\) was due to better yield attributes like pod yield plant\(^{-1}\) (10.10 g plant\(^{-1}\)) (Table 2), number of pods plant\(^{-1}\) (20.6 plant\(^{-1}\)) and test weight (33.1g) (Table 1). It might be due to the fact that groundnut plants compensate for earlier drought period by initiating a flush of reproductive parts after the relief of stress (Dutta and Mondal, 2006). It’s been reported that water stress during the vegetative or early flowering stages is not detrimental and sometimes actually increases yield (Rao et al., 1985; Nautiyal et al. 1999). However, withholding of two irrigations at pegging and pod development stage (I\(_1\)) and withholding of irrigation at pegging, pod filling and kernel development stage (I\(_2\)), drastically reduced pod yield to the extent of 32.0% (1,950 kg ha\(^{-1}\)) and 70.6% (842 kg ha\(^{-1}\)) respectively, over the no moisture stress (I\(_1\)). It might be due to inadequate availability soil moisture at reproductive stages, like pod filling and kernel development stages, as these are the critical stages for crop which hinders the translocation of photosynthates from leaves to fruiting parts and affect the pod formation and pod yield. This results in lower number of pods plant\(^{-1}\), lower pod dry weight plant\(^{-1}\) and lower kernel hundred weight (Assan and Sani, 1985). Moisture stress during seed filling stage is known to accelerate the rate of seed maturation causing yield loss due to shortened grain filling phase (Boote et al. 2003). A slight reduction of water requirement of groundnut does not significantly affect the pod yield. However, above 20 per cent water stress affects the pod yield (Aruna et al. 2017). There was a significant difference among the different water regimes with respect to shelling percentage, I\(_1\) (no stress) recorded significantly higher shelling percentage (69.6%), but was found on par (68.9%) with the treatment I\(_2\) (stress at pegging stage).

The perusal of yield data revealed that groundnut yield differed significantly among the groundnut genotypes. The genotype Dh-86 (2,375 kg ha\(^{-1}\)) recorded significantly superior pod yield over other genotypes like Dh-101 (2,215 kg ha\(^{-1}\)), K-9 (2,048 kg ha\(^{-1}\)) and G2-52 (1,880kg ha\(^{-1}\)). The increase in grain yield of Dh-86 over other genotypes was to the extent of 6.75 per cent, 13.77 per cent and 20.84 per cent, respectively. The increased in the pod yield (2,375 kg ha\(^{-1}\)) and haulm yield (3,815 kg ha\(^{-1}\)) was due to higher yield parameters like number of pods per plant (20 plant\(^{-1}\)) and kernel weight (32.2 g) (Table 1). Among the different genotypes, Dh-86 (G\(_1\)) recorded significantly higher shelling percentage (67.8 %) and the lowest shelling percentage was recorded with G2-52 (G\(_2\)) (64.6 %), respectively (Table 1). Similar type of findings with different cultivars suggesting differential response were observed by Vorasoot et al. (2003).
### Table 1: Number of pods, test weight and shelling percentage of groundnut as influenced by different irrigation regimes and genotypes.

| Treatment | Number of pods plant\(^{-1}\) | Test weight (g) | Shelling percentage |
|-----------|-------------------------------|----------------|--------------------|
|           | I\(_1\) I\(_2\) I\(_3\) I\(_4\) | I\(_1\) I\(_2\) I\(_3\) I\(_4\) | I\(_1\) I\(_2\) I\(_3\) I\(_4\) |
| Irrigations (I) |                               |                 |                   |
| I\(_1\) | 26.0 25.5 22.0 6.6 | 20.0 34.9 34.5 31.0 | 28.3 32.2 71.1 70.3 | 67.2 63.0 67.8 |
| I\(_2\) | 23.3 22.7 19.6 5.5 | 17.8 34.3 33.1 30.4 | 26.2 31.0 70.0 68.8 | 66.2 62.7 66.9 |
| I\(_3\) | 23.2 19.0 18.9 5.7 | 16.7 34.5 31.9 29.5 | 25.0 30.2 69.2 69.1 | 65.0 61.0 66.1 |
| I\(_4\) | 21.6 15.4 14.6 5.4 | 14.2 32.2 33.0 29.5 | 23.8 29.6 68.2 67.7 | 64.5 58.0 64.6 |
| Mean   | 23.5 20.6 18.8 5.8 | 18.8 34.0 33.1 30.1 | 25.8 29.6 69.6 68.9 | 65.7 61.2 |
| Genotypes (G) |                               |                 |                   |
| G\(_1\) | 30.0 29.5 27.0 7.5 | 24.0 39.9 38.5 35.0 | 32.0 31.5 71.1 70.3 | 67.2 62.7 66.9 |
| G\(_2\) | 27.3 26.7 24.5 7.0 | 21.5 37.5 36.0 33.0 | 29.5 29.0 70.0 68.8 | 66.2 61.0 66.1 |
| G\(_3\) | 27.2 19.0 18.5 5.5 | 16.7 34.5 31.9 29.5 | 25.0 30.2 69.2 69.1 | 65.0 61.0 66.1 |
| G\(_4\) | 25.6 15.2 14.0 4.5 | 12.2 31.0 31.5 28.5 | 21.5 28.6 67.7 66.5 | 64.0 56.0 64.6 |
| Mean   | 26.5 23.6 21.5 6.5 | 19.8 35.0 34.5 31.5 | 24.8 26.6 68.8 67.7 | 64.5 58.0 64.6 |

For comparing S. Em. ± C.D. (P = 0.05) means of Irrigation (I)

- I\(_1\): Control : 7 irrigations at 15 days interval from sowing to 105 DAS.
- I\(_2\): Stress at pegging stage : withdrawal of one irrigation between 45 - 60 DAS.
- I\(_3\): Stress at pegging and pod filling stage : withdrawal of 2 irrigations between 45 - 75 DAS.
- I\(_4\): Stress at pegging, pod filling and kernel development stage : withdrawal of 4 irrigations between 45 - 105 DAS.

For comparing S. Em. ± C.D. (P = 0.05) means of Genotypes (G)

- G\(_1\): Dh-86
- G\(_2\): Dh-101
- G\(_3\): K-9
- G\(_4\): G2-52

### Table 2: Pod yield, haulm yield and harvest index of groundnut as influenced by different irrigation regimes and genotypes.

| Treatment | Pod yield (kg ha\(^{-1}\)) | Haulm yield (kg ha\(^{-1}\)) | Harvest index (%) |
|-----------|-----------------------------|-----------------------------|-------------------|
|           | I\(_1\) I\(_2\) I\(_3\) I\(_4\) | I\(_1\) I\(_2\) I\(_3\) I\(_4\) | I\(_1\) I\(_2\) I\(_3\) I\(_4\) |
| Irrigations (I) |                               |                 |                   |
| I\(_1\) | 3,191 3,168 2,194 949 | 2,376 4,910 4,881 3,574 | 1,897 3,816 39.5 39.2 | 38.0 33.3 37.5 |
| I\(_2\) | 3,010 2,963 2,024 863 | 2,215 4,635 4,746 4,126 | 1,562 3,767 39.4 38.4 | 32.9 35.6 36.6 |
| I\(_3\) | 2,730 2,763 1,919 783 | 2,048 4,654 4,612 3,524 | 1,676 3,617 37.0 37.5 | 35.2 31.8 35.4 |
| I\(_4\) | 2,548 2,537 1,664 773 | 1,881 4,565 4,353 3,325 | 1,649 3,473 35.8 36.8 | 33.4 31.9 34.5 |
| Mean   | 2,870 2,858 1,950 842 | 2,691 4,648 3,638 3,169 | 1,696 3,790 37.9 34.9 | 33.2 |
| Genotypes (G) |                               |                 |                   |
| G\(_1\) | 3,191 3,168 2,194 949 | 2,376 4,910 4,881 3,574 | 1,897 3,816 39.5 39.2 | 38.0 33.3 37.5 |
| G\(_2\) | 3,010 2,963 2,024 863 | 2,215 4,635 4,746 4,126 | 1,562 3,767 39.4 38.4 | 32.9 35.6 36.6 |
| G\(_3\) | 2,730 2,763 1,919 783 | 2,048 4,654 4,612 3,524 | 1,676 3,617 37.0 37.5 | 35.2 31.8 35.4 |
| G\(_4\) | 2,548 2,537 1,664 773 | 1,881 4,565 4,353 3,325 | 1,649 3,473 35.8 36.8 | 33.4 31.9 34.5 |
| Mean   | 2,870 2,858 1,950 842 | 2,691 4,648 3,638 3,169 | 1,696 3,790 37.9 34.9 | 33.2 |

For comparing S. Em. ± C.D. (P = 0.05) means of Irrigation (I)

- I\(_1\): Control : 7 irrigations at 15 days interval from sowing to 105 DAS.
- I\(_2\): Stress at pegging stage : withdrawal of one irrigation between 45 - 60 DAS.
- I\(_3\): Stress at pegging and pod filling stage : withdrawal of 2 irrigations between 45 - 75 DAS.
- I\(_4\): Stress at pegging, pod filling and kernel development stage : withdrawal of 4 irrigations between 45 - 105 DAS.

For comparing S. Em. ± C.D. (P = 0.05) means of Genotypes (G)

- G\(_1\): Dh-86
- G\(_2\): Dh-101
- G\(_3\): K-9
- G\(_4\): G2-52

Days after sowing NS: Non-significant.
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Table 3: Water use efficiency and economics of groundnut as influenced by different irrigation regimes and genotypes.

| Treatment | Water use efficiency (kg/ha-mm) | Gross return (Rs. ha⁻¹) | Net return (Rs. ha⁻¹) |
|-----------|---------------------------------|-------------------------|----------------------|
|           | Mean                            | S.E.m. ±                 | C.D. (P = 0.05)     |
| I × G     | I₁ × G₁                         | I₁ × G₂                 | I₁ × G₃              |
|           | I₂ × G₁                         | I₂ × G₂                 | I₂ × G₃              |
|           | I₃ × G₁                         | I₃ × G₂                 | I₃ × G₃              |
| Mean      |                                |                         |                     |
| Genotypes (G) |                                 |                         |                     |
| G₁        | 5.3                             | 4.72                    | 249.19               |
| G₂        | 5.2                             | 5.0                     | 449.19               |
| G₃        | 4.9                             | 4.2                     | 87.76                |
| G₄        | 5.5                             | 5.8                     | 1,25,227             |
| Mean      | 5.3                             | 4.72                    | 249.19               |
| Irrigations (I) |                                 |                         |                     |
| I₁        | Control : 7 irrigations at 15 days interval from sowing to 105 DAS. | 2707.32                | 62,055               |
| I₂        | Stress at pegging stage (I₂) recorded significantly higher WUE (6.9 kg/ha-mm) compared to other treatment combinations (Table 3). Field WUE and dry matter production, including economic yield were increased by imposing a transient deficit in soil moisture during the vegetative phase in groundnut (Nautiyal et al. 2017). |
| I₃        | Stress at pegging and pod filling stage (I₃) recorded significantly higher WUE (6.2 kg/ha-mm) and net return (78,362 ha⁻¹) compared to other genotype. Among the genotypes, Dh-86 (5.3 kg/ha-mm) recorded the significantly higher WUE over other genotypes and the least was observed in G2-52(4.2 kg/ha-mm). Cultivation of genotype Dh-86 with stress at pegging stage (I₁) recorded the significantly higher WUE (6.9 kg/ha-mm) compared to other treatment combinations (Table 3). Field WUE and dry matter production, including economic yield were increased by imposing a transient deficit in soil moisture during the vegetative phase in groundnut (Nautiyal et al. 2017). |

**Effect of moisture stress on water use efficiency of groundnut genotypes**

Water use efficiency (WUE; kg/ha-mm) was influenced by different water regimes and presented in Table 3. Stress at pegging stage (I₁) recorded significantly higher WUE (6.2 kg/ha-mm) followed by (I₂) stress at pegging, pod filling and kernel development stage(I₃) recorded significantly lower WUE (2.5 kg/ha-mm). Among the genotypes, Dh-86 (5.3 kg/ha-mm) recorded the significantly higher WUE over other genotypes and the least was observed in G2-52 (4.2 kg/ha-mm). Cultivation of genotype Dh-86 with stress at pegging stage (I₁) recorded the significantly higher WUE (6.9 kg/ha-mm) compared to other treatment combinations (Table 3). Field WUE and dry matter production, including economic yield were increased by imposing a transient deficit in soil moisture during the vegetative phase in groundnut (Nautiyal et al. 2017).

**Effect of moisture stress on economics of groundnut genotypes**

Higher gross return (1,24,670 ha⁻¹) and net return (82,388 ha⁻¹) were recorded with I₂ (stress at pegging stage). However it was at par with no moisture stress treatment (I₃). It was mainly due to higher pod yield and higher haulm yield (Table 3). Among the various genotypes Dh-86 (G₁) was recorded significantly higher gross return (1,03,594 ha⁻¹) and net return (62,055 ha⁻¹) compared to other genotypes. This was attributed to higher pod yield and haulm yield resulting in higher net return and gross return compared to other genotypes. Among interactions, significantly higher gross return (1,37,937 ha⁻¹) and net return (95,655 ha⁻¹) was recorded with I₁G₁ which was at par with I₃G₁ (1,38,946 ha⁻¹ and 95,639 ha⁻¹).

**Conclusion**

The results showed that mild deficit moisture regime at pegging is feasible, but the same stress at pegging, pod filling and kernel development stage (I₃) are not feasible. It negatively affects yield and yield attributes and profitability of groundnut production in the NTZ of Karnataka. From this experiment it can be concluded that cultivation of genotype Dh-86 with mild stress at pegging stage (I₁) by skipping one irrigation could be the best condition for groundnut production to improve net profit of production and enhance WUE.
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