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## Research Article

# MORPHO-PHYSIOLOGICAL INDICES FOR DROUGHT TOLERANCE IN PIGEONPEA [C*ajanus cajan* L. Millsp.] GENOTYPES UNDER RAINFED AND IRRIGATED CONDITIONS

**SURESH K.*, BHADAURIA H.S., SATISH K. AND NEETU S.**

Department of Genetics and Plant Breeding, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, 385506, Gujarat, India
*Corresponding Author: Email-physiologistnaidu@gmail.com

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**Abstract-** A field experiment was carried at Centre of Excellence for Research on Pulses, Sardar krushinagar Dantiwada Agricultural University (S.D.A.U.), Sardarkrushinagar, Gujarat during *kharif* 2013 to study the morpho-physiological indices for drought tolerance of different pigeonpea genotypes under rainfed and irrigated conditions. Significant differences exhibited amongst the genotypes for initial and final plant stand, days to flowering, days to maturity, 100 seed weight, harvest index. The genotypes SKNP 1004, SKNP 1005 and SKNP 0805 recorded minimum percent reduction in yield due to moisture stress. Relative water content (RWC), Drought Tolerance Efficiency (DTE) were found to be the most useful parameters while selecting genotypes for drought tolerance. The genotypes SKNP 1004, SKNP 1005, SKNP 0805 and BANAS were promising for yield and yield contributing characters in both rainfed and irrigated conditions.

**Keywords**- Pigeonpea, Relative water content, Drought Tolerance Efficiency

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## Introduction

Pigeonpea [C*ajanus cajan* L. Millsp.] is commonly known as redgram or arhar or tur in India, it is tropical crops predominantly grown during the *Kharif* season both as a sole and intercrop under wide range of agro-ecological situations. Being a pulse crop, pigeonpea enriches soil through symbiotic nitrogen fixation, releases soil-bound phosphorous, recycles the soil nutrients, adds organic matter and other nutrients that make pigeonpea an ideal crop for sustainable of agriculture [1]. Pigeonpea is often considered as a drought tolerant crop and a post-rainy season crop is often subjected to water stress at one or several stages of crop growth and development, since it is a long duration crop with a large variation for maturity period. As a result, it is widely adapted to a range of environments and cropping systems. The variations for maturity have direct relevance on the survival and fitness of the crop in different agro-ecological niches [2]. The situation becomes even worse for medium and long duration pigeonpea as their flowering and pod-filling stages coincide acute soil moisture deficit in absence of any supplementary irrigation. Terminal drought which occurs at reproductive phase is a major constraint to pigeonpea production.

Legumes constitute an important component of drought prone agriculture. The water stress reduces the yield of grain legumes remarkbly. Drought is an important environmental stress factor limiting pigeonpea production worldwide. The water deficits, which are a consequence of either contagious or transitory periods of drought, cause significant yield reductions on presently cultivated regions, and greatly restrict the cultivation of crops on arid and semiarid regions [3]. Drought triggers a wide variety of plant responses, ranging from cellular metabolism to changes in growth rate and crop yield. Drought stress progressively decreases $CO_2$ assimilation rate due to reduced stomatal conductance. It reduces leaf size, stem extension, root proliferation, which affects plant water relations and reduces water-use efficiency. It disrupts photosynthetic pigments and gas exchange leading to a reduction in plant growth and development. The morphological and physiological changes in response to drought stress can be used to help identify resistant genotypes or produce new varieties of crops for better productivity under drought stress [4]. The reactions of plants to drought stress depend on the intensity and duration of stress as well as the plant species and its stage of growth [5]. Consequent upon the productivity of Pigeonpea is unstable and low under drought that is why varieties are needed with good stable yield and resistance to drought. Therefore, the study was undertaken with the objective to assess and identify morpho-physiological traits for drought tolerance.

## Materials and Methods

Twenty genotypes were evaluated under rainfed and irrigated conditions separately in RBD with three replications at at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardar krushinagar, Gujarat during *Kharif* season 2013. The seeds were sown on 12$^{th}$ July, 2013 with the spacing of 60cm (Row to Row) 20 cm (Plant to Plant). The recommended packages of practices were followed to raise the good crop. One set was raised under normal irrigated condition while the other was raised under rainfed condition (one irrigation was given for proper germination). Additional four irrigations at 30-35 days interval were given to irrigated set.

The observations for initial plant population were counted when the plant reaches 60 days from the date of sowing and final plant population were counted at the time of harvest. Days to 50% flowering and days to maturity was recorded on plot basis. Randomly five plants were tagged in net plot area for recording the observations of 100 seed weight (g), Seed yield / plant (g). Harvest index was calculated by using the following formula.

$$\text{Harvest index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

Relative water content of the leaves estimated by using the method [6].
Drought Tolerance Efficiency was measured by using the formula [7].

$$\mathrm{DTE} = \frac{\text{Yield under stress}}{\text{Yiled under no stress}} \times 100$$

The statistical analysis for various characters was carried out at computer centre, department of Agricultural Statistics, Chimanbhai Patel College of Agriculture, Sardarkrushinagar according by the method suggested [8].

## Results and Discussion

### Initial and final plant stand

The data pertaining to the mean initial plant stand counted at 60 days after sowing were presented in [Table-1] revealed that the genotypic differences were found non-significant under rainfed as well as irrigated conditions whereas data belongs to the mean final plant stand under rainfed conditions significant differences were found among the different genotypes. The genotype SKNP 1004 recorded significantly highest final plant stand, which was at par with the genotypes SKNP 0805, SKNP 1109, GT 101, SKNP 1005 and SKNP 1021 though remaining genotypes have significant difference with the SKNP 1004 under rainfed condition. In case of irrigated condition the mean final plant stand were found non-significant among the various genotypes. The limited root volume explored by seedlings exposes them to more negative soil water potentials than plants with larger root systems. Initially, growth stops and foliage wilts as stress further progress plants may eventually die. All these together causes decline in plant stand. These results were evident by the findings of [9].

### Days to flowering

Earliness in flower initiation were observed in the genotype UPAS 120 over to rest of all other genotypes. Under rainfed as well as irrigated conditions earliness in flower initiation was observed in the genotype UPAS 120 leaving all other genotypes far beyond the line, while remaining genotypes were showed difference to flower initiation at par with each other [Table-1] [Fig-1]. The lack of available moisture usually reduces the length of the growing season. Plants try to complete its life cycle as early as possible and moisture stress creates internal stress on different parts, which quickens flowering. Early flowering is one of major component of drought escape. Similar finding were also reported by [10].

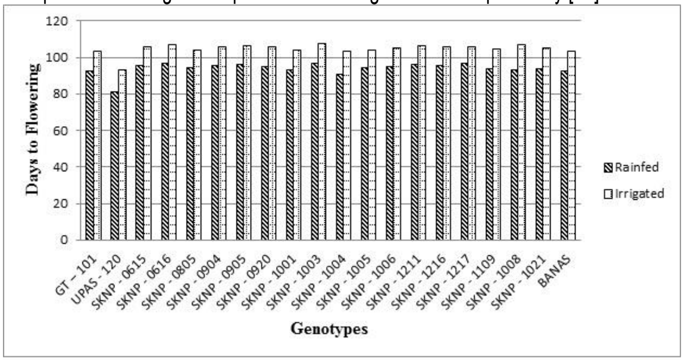


**Fig-1 Effect of rainfed and irrigated conditions on days to flowering**

### Days to maturity

The genotype UPAS 120 took minimum days to maturity as compared to all other genotypes under both environments whereas other genotypes found at par to each other in both conditions [Table-1] [Fig-2]. Crops mature early during moisture stress and even when temperatures were higher. Early maturity is attributed to hastening phenological phases as a means of drought escape. Present study is supported by [11].

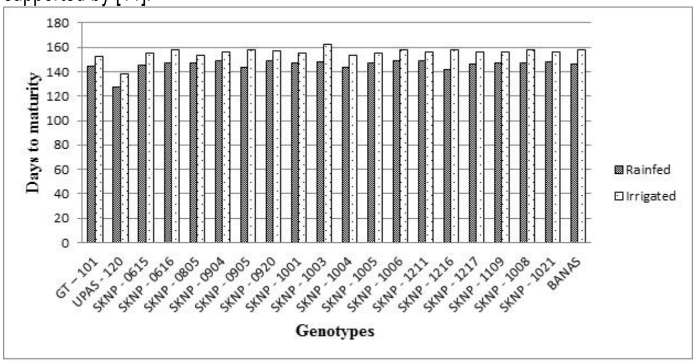


**Fig-2 Effect of rainfed and irrigated conditions on days to maturity**

**Table-1** *Vegetative growth and Physiological parameters related to drought characteristics as influenced by pigeonpea genotypes under rainfed and irrigated conditions*

| Genotypes | Initial Plant Stand | | Final Plant Stand | | Days to flowering | | Days to maturity | | 100 seed weight (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_0$ | $I_1$ | $I_0$ | $I_1$ | $I_0$ | $I_1$ | $I_0$ | $I_1$ |
| GT 101 | 31.67 | 36.00 | 25.67 | 31.33 | 92.67 | 103.33 | 144.67 | 152.33 | 8.79 | 11.05 |
| UPAS 120 | 29.67 | 34.33 | 23.00 | 30.67 | 81.33 | 93.33 | 127.33 | 138.33 | 7.99 | 9.62 |
| SKNP 0615 | 26.33 | 34.67 | 18.00 | 29.00 | 95.67 | 106.00 | 145.67 | 155.33 | 8.01 | 9.61 |
| SKNP 0616 | 27.67 | 34.33 | 19.67 | 28.67 | 97.00 | 107.33 | 147.67 | 158.00 | 8.07 | 10.62 |
| SKNP 0805 | 32.67 | 36.67 | 27.00 | 33.33 | 94.33 | 104.00 | 147.33 | 153.33 | 8.76 | 11.23 |
| SKNP 0904 | 31.33 | 35.33 | 20.67 | 31.67 | 95.67 | 105.67 | 148.67 | 156.67 | 8.00 | 10.33 |
| SKNP 0905 | 30.33 | 32.67 | 22.00 | 31.33 | 96.00 | 106.33 | 143.67 | 158.00 | 7.86 | 9.91 |
| SKNP 0920 | 31.33 | 34.67 | 24.00 | 31.33 | 95.33 | 106.00 | 148.67 | 157.33 | 7.94 | 11.01 |
| SKNP 1001 | 31.00 | 32.67 | 22.67 | 30.67 | 93.33 | 104.00 | 147.00 | 155.67 | 7.89 | 9.96 |
| SKNP 1003 | 25.67 | 31.67 | 17.00 | 27.67 | 97.00 | 107.67 | 148.33 | 162.33 | 6.83 | 9.51 |
| SKNP 1004 | 33.33 | 39.00 | 28.33 | 33.33 | 91.00 | 103.33 | 144.00 | 153.33 | 9.04 | 11.47 |
| SKNP 1005 | 32.33 | 37.67 | 25.33 | 35.67 | 94.67 | 104.33 | 147.67 | 155.33 | 8.92 | 11.34 |
| SKNP 1006 | 28.33 | 32.00 | 19.33 | 31.67 | 95.00 | 105.00 | 149.00 | 158.00 | 7.62 | 9.83 |
| SKNP 1211 | 31.00 | 32.33 | 22.67 | 30.33 | 96.00 | 106.67 | 148.67 | 156.67 | 8.01 | 9.75 |
| SKNP 1216 | 31.33 | 32.67 | 21.33 | 28.33 | 95.67 | 105.67 | 141.67 | 158.00 | 7.71 | 11.35 |
| SKNP 1217 | 31.00 | 32.33 | 23.67 | 30.00 | 96.67 | 106.00 | 146.00 | 156.67 | 7.80 | 10.86 |
| SKNP 1109 | 32.00 | 36.33 | 26.67 | 32.67 | 93.67 | 104.67 | 147.33 | 156.33 | 8.02 | 11.48 |
| SKNP 1008 | 31.00 | 33.67 | 22.00 | 31.33 | 93.00 | 107.33 | 147.67 | 157.67 | 7.57 | 10.49 |
| SKNP 1021 | 31.33 | 35.67 | 25.00 | 31.00 | 94.00 | 105.00 | 148.33 | 156.00 | 8.19 | 11.25 |
| BANAS | 30.67 | 35.00 | 20.00 | 30.67 | 92.67 | 103.67 | 146.33 | 157.67 | 8.42 | 9.65 |
| S.Em$\pm$ | 1.54 | 1.52 | 1.43 | 1.59 | 1.84 | 1.63 | 3.01 | 2.46 | 0.36 | 0.33 |
| CD at 5 % | NS | NS | 4.10 | NS | 5.26 | 4.69 | 8.60 | 7.03 | 1.03 | 0.93 |
| CV % | 8.77 | 7.63 | 10.94 | 8.85 | 3.39 | 2.70 | 3.57 | 2.74 | 7.70 | 5.38 |

$I_0$ :Rainfed condition, $I_1$ : Irrigated condition

**100 seed weight (g)**

The 100 seed weight of both rainfed and irrigated conditions uncovered significant differences among the different genotypes [Table-1] [Fig-3]. Genotype SKNP 1004 registered highest 100 seed weight and it was found superior over to rest of all other genotypes except SKNP 1005, GT 101, SKNP 0805, BANAS, SKNP 1021, SKNP 0616, SKNP 1109, SKNP 0615 and SKNP 1211.

In irrigated condition the maximum 100 seed weight was obtained in the genotype SKNP 1109 followed by the genotypes SKNP 1004, SKNP 1216, SKNP 1005, SKNP 1021, SKNP 0805, GT 101, SKNP 0920, SKNP 1217 and SKNP 0616 as compared to the remaining genotypes.

Concerning with 100 seed weight it was differed under both conditions, reduced 100 seed weight under moisture stress was observed due to detrimental effects of drought on $CO_2$ assimilation. The results were concur with the findings of [12].

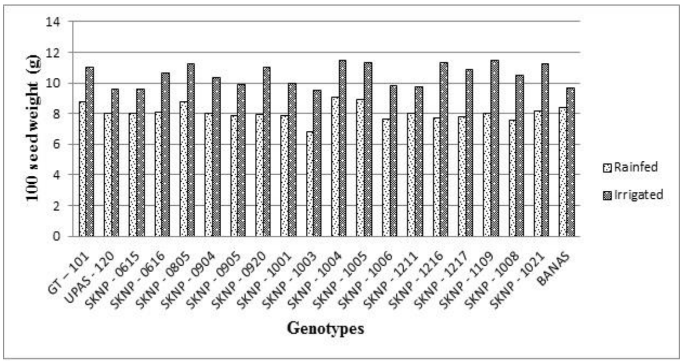


**Fig-3 Effect of rainfed and irrigated conditions on 100 seed weight**

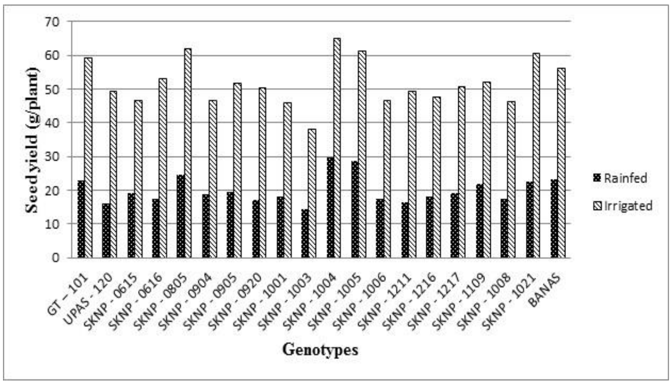


**Fig-4 Effect of rainfed and irrigated conditions on seed yield**

**Seed yield (g/plant)**

Mean seed yield per plant for both rainfed and irrigated conditions brought out the genotypic differences were conceived statistically significant [Table-2] [Fig-4]. In the present experiment, maximum seed yield was recorded in the genotype SKNP 1004 followed by SKNP 1005 over to rest of all other genotypes. Again perusal of the data indicated that SKNP 0805 had more seed yield along with the genotypes BANAS, GT 101 and SKNP 1021 as compared to genotypes UPAS 120, SKNP 0615, SKNP 0616, SKNP 0904, SKNP 0905, SKNP 0920, SKNP 1001, SKNP 1006, SKNP 1211, SKNP 1216, SKNP 1217, SKNP 1109 and SKNP 1008 under rainfed condition.

**Table-2** *Yield and yield contributing characters influenced by pigeonpea genotypes under rainfed and irrigated conditions*

| Genotypes | Seed yield (g/plant) | | Harvest index (%) | | Relative Water Content (%) | | Drought Tolerance Efficiency (%) |
|---|---|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | $I_0$ | $I_1$ | $I_0$ | $I_1$ | |
| GT 101 | 23.02 | 59.21 | 14.37 | 21.64 | 51.65 | 64.25 | 38.85 |
| UPAS 120 | 15.96 | 49.29 | 9.25 | 18.64 | 46.26 | 54.32 | 32.40 |
| SKNP 0615 | 19.21 | 46.66 | 12.13 | 17.05 | 44.96 | 53.21 | 41.21 |
| SKNP 0616 | 17.58 | 53.28 | 10.65 | 21.07 | 46.49 | 54.42 | 32.95 |
| SKNP 0805 | 24.74 | 61.87 | 13.46 | 22.37 | 52.80 | 67.95 | 40.06 |
| SKNP 0904 | 18.77 | 46.50 | 12.20 | 18.63 | 47.13 | 53.30 | 40.56 |
| SKNP 0905 | 19.55 | 51.84 | 10.93 | 18.99 | 45.14 | 54.02 | 37.74 |
| SKNP 0920 | 17.16 | 50.25 | 9.66 | 19.50 | 47.48 | 60.99 | 34.29 |
| SKNP 1001 | 18.04 | 45.94 | 11.10 | 17.54 | 46.50 | 58.26 | 39.25 |
| SKNP 1003 | 14.25 | 38.22 | 8.47 | 13.66 | 44.54 | 52.84 | 37.24 |
| SKNP 1004 | 29.81 | 65.11 | 16.71 | 23.44 | 55.15 | 71.27 | 45.94 |
| SKNP 1005 | 28.71 | 61.28 | 16.37 | 21.81 | 51.77 | 64.37 | 46.89 |
| SKNP 1006 | 17.64 | 46.62 | 9.71 | 17.50 | 47.39 | 53.50 | 38.02 |
| SKNP 1211 | 16.59 | 49.27 | 8.65 | 17.66 | 47.53 | 57.69 | 33.64 |
| SKNP 1216 | 18.25 | 47.67 | 9.67 | 17.31 | 48.71 | 55.98 | 38.71 |
| SKNP 1217 | 19.19 | 50.65 | 9.75 | 18.42 | 47.39 | 58.68 | 37.81 |
| SKNP 1109 | 21.88 | 52.11 | 12.33 | 20.29 | 50.14 | 62.99 | 42.10 |
| SKNP 1008 | 17.56 | 46.43 | 9.63 | 16.89 | 44.07 | 58.04 | 38.23 |
| SKNP 1021 | 22.69 | 60.76 | 13.49 | 21.05 | 44.78 | 61.57 | 37.42 |
| BANAS | 23.30 | 56.35 | 13.20 | 21.09 | 49.19 | 61.22 | 41.40 |
| S.Em± | 0.98 | 2.37 | 0.64 | 0.89 | 2.17 | 2.36 | 1.98 |
| CD at 5 % | 2.79 | 6.79 | 1.84 | 2.55 | 6.20 | 6.74 | 5.68 |
| CV % | 8.37 | 7.92 | 9.62 | 7.99 | 7.82 | 6.92 | 8.87 |

$I_0$: Rainfed condition, $I_1$: Irrigated condition, DTE: Drought Tolerance Efficiency

In irrigated condition, SKNP 1004 once again recorded highest seed yield and it was at par with genotypes SKNP 0805, SKNP 1005, SKNP 1021 and GT 101.

Drought inhibited growth by reducing rate of cell division and cell expansion, leaf size, stem elongation as well as root proliferation, by disturbing stomatal oscillations, metabolic activities, plant water and nutrient relations, loss of pollen and stigma viability which affects yield components and all together decreases seed yield. Moisture stress reduced yield due to poor partitioning operated along with terminal drought stress. The present study was supported by [13].

**Harvest index (%)**

The genotype SKNP 1004 followed by SKNP 1005. Again reviewed the data indicated that GT 101 had more harvest index and it was at par with SKNP 1021, SKNP 0805 and BANAS over rest of the genotypes under rainfed condition [Table-2] [Fig-5]. The utmost harvest index in irrigated condition was observed in the genotype SKNP 1004 and it was at par with SKNP 0805, SKNP 1005, GT 101, BANAS, SKNP 0616 and SKNP 1021 over remaining all other genotypes. The ability of genotypes to produce more biomass in stress conditions also produced more seed yield. The genotypes with maximum harvest index under stress conditions are reported as drought tolerant genotypes. Reduction in assimilate supply, low pod number, repressed seed number all together decreases the harvest index. These results associated with the findings of [14].

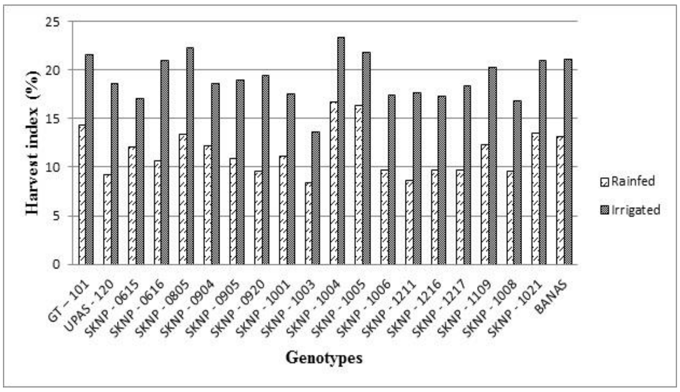


**Fig-5 Effect of rainfed and irrigated conditions on harvest index**

**Relative Water Content (%)**

Perusal of the data related to relative water content indicated that SKNP 1004 showed statistically superior values of RWC along with SKNP 0805, SKNP 1005, GT 101, SKNP 1109 and BANAS over all other genotypes [Table-2] [Fig-6].

Under irrigated condition highest value of relative water content was obtained by SKNP 1004 and it was at par with SKNP 0805. Critically observing the table again showed that SKNP 1005 obtained more value of RWC and it had significant difference with SKNP 1216, SKNP 0616, UPAS 120, SKNP 0905, SKNP 1006, SKNP 0904, SKNP 0615 and at par with the remaining genotypes.

Adverse environmental factors cause cell membranes to lose selective permeability, cellular integrity and capacity for retention of intracellular substances. The cellular membrane dysfunction due to water stress causes an increase in the permeability and ion leakage. Thus increase in cell membranes leakiness is interpreted as an injury and loss of membrane integrity associated with a decreasing RWC, and this might accelerate senescence processes. The low value of RWC was recorded under non-irrigated condition, which might be due to the impact of lower soil moisture supply. Similar results of decrease in Relative Water Content were obtained by [15].

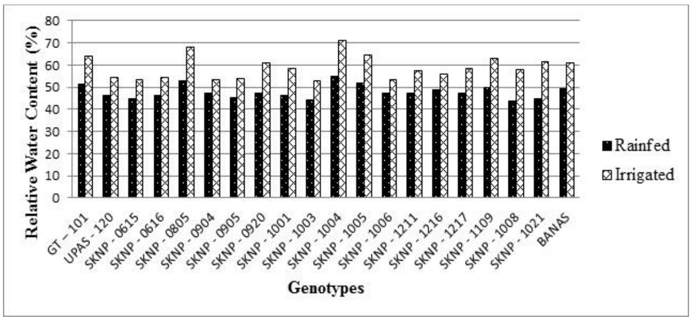


**Fig-6 Effect of rainfed and irrigated conditions on Relative Water Content**

**Drought Tolerance Efficiency (DTE) (%)**

The calculated data of mean DTE indicated that the genotype SKNP 1005 showed maximum value of DTE and it was at par with SKNP 1004, SKNP 1109, BANAS and SKNP 0615. Again critically watching the data revealed that SKNP 0904 recorded higher DTE and it showed significant difference with SKNP 1211, SKNP 0920 [Table-2] [Fig-7].

Drought resistant genotype had the highest DTE and minimum reduction in seed yield due to moisture stress and maintained highest harvest index. Results of this study had showed parallelism with the findings of [16].

**Conclusion**

The study conducted revealed that SKNP 1004 had the best performance in terms of final plant stand, 100 seed weight, yield, harvest index, Relative Water Content and Drought Tolerance Efficiency. Although, SKNP 1005, SKNP 0805 and BANAS showed minimum yield loss after SKNP 1004. Generally, SKNP 1003, UPAS 120 and SKNP 1211 recorded poor grain filling and quality in rainfed condition. While in case of irrigated conditions SKNP 1003, SKNP 1001, SKNP 1008 are poor performers for yield. Even though all the genotypes survived the inadequate rainfall for most of the growing periods, grain yield produced was varied. Hence SKNP 1004 was ranked most assuring genotype for both rainfed and irrigated conditions followed by SKNP 1005, SKNP 0805 and BANAS. Therefore, these genotypes with the drought tolerance should be crossed with high yielding genotypes for mitigating drought in pigeonpea.

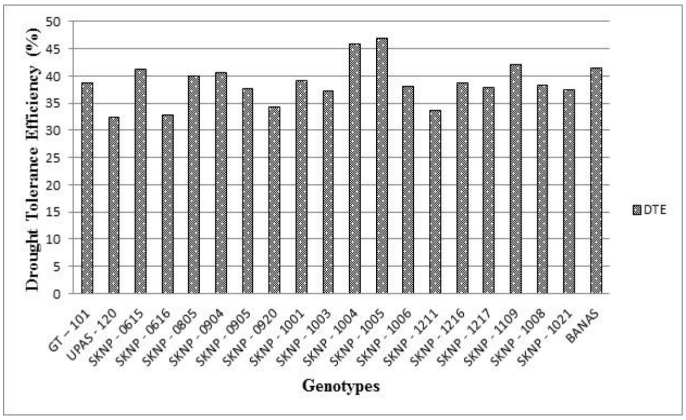


**Fig-7 Effect of rainfed and irrigated conditions on Drought Tolerance Efficiency (DTE)**

**Conflict of Interest: None declared**

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