IDENTIFICATION OF RAGI GENOTYPES FOR DROUGHT TOLERANCE, HIGH YIELD AND SEED QUALITY PARAMETERS UNDER *KHARIF* RAINFED CONDITIONS

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B.Sc. (Ag.)

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(CROP PHYSIOLOGY)

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IDENTIFICATION OF RAGI GENOTYPES FOR DROUGHT TOLERANCE, HIGH YIELD AND SEED QUALITY PARAMETERS UNDER *KHARIF* RAINFED CONDITIONS

BY

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B.Sc. (Ag.)

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2016

DECLARATION

I, **Ms. K. APARNA,** hereby declare that the thesis entitled **"IDENTIFICATION OF RAGI GENOTYPES FOR DROUGHT TOLERANCE, HIGH YIELD AND SEED QUALITY PARAMETERS UNDER *KHARIF* RAINFED CONDITIONS"** submitted to the Acharya N.G. Ranga Agricultural University, for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is the result of original research work done by me. I also declare that no material contained in this thesis has been published earlier in any manner.

Place : Tirupati

Date :

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CERTIFICATE

Ms. K. APARNA has satisfactorily prosecuted the course of research and that the thesis entitled **"IDENTIFICATION OF RAGI GENOTYPES FOR DROUGHT TOLERANCE, HIGH YIELD AND SEED QUALITY PARAMETERS UNDER *KHARIF* RAINFED CONDITIONS"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has not been previously submitted by him for a degree of any university.

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CERTIFICATE

This is to certify that the thesis entitled **"IDENTIFICATION OF RAGI GENOTYPES FOR DROUGHT TOLERANCE, HIGH YIELD AND SEED QUALITY PARAMETERS UNDER *KHARIF* RAINFED CONDITIONS"** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture) in CROP PHYSIOLOGY** to the Acharya N.G. Ranga Agricultural University, Guntur, is a record of the bonafide original research work carried out by **Ms. K. APARNA** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	At the rate
°C	:	Degree Celsius
°E	:	Degree east
°N	:	Degree north
µg	:	Micro grams
Ca	:	Calcium
CD	:	Critical difference
cm	:	Centimetre
cm^2	:	Square centimeter
CSI	:	Chlorophyll stability index
DAP	:	Di ammonium phosphate
DAS	:	Days after sowing
day^{-1}	:	Per day
dSm^{-1}	:	Decisiemen per metre
DTI	:	Drought tolerance index
et al.	:	and co-workers
Fe	:	Iron
Fig	:	Figure
g	:	Gram
g^{-1}	:	Per gram
ha^{-1}	:	Per hectare
HI	:	Harvest index
K	:	Potassium
Kg	:	Kilogram
l	:	Litre
LAD	:	Leaf area duration
LAI	:	Leaf area index
m	:	Million
m.ha	:	Million hectare
m.t	:	Million tonnes
m^{-2}	:	Per square meter

Mg	:	Magnesium
mg	:	Milligram
MOP	:	Muriate of potash
N	:	Nitrogen
NAR	:	Net assimilation rate
NS	:	Non-significant
P	:	Phosphorous
$Plant^{-1}$	:	Per plant
ppm	:	Parts per million
r	:	Correlation Co-efficient
RDF	:	Recommended dose fertilizers
RWC	:	Relative water content
S	:	Sulphur
SCMR	:	SPAD chlorophyll meter reading
SEm	:	Standard error mean
SLA	:	Specific leaf area
SPAD	:	Soil plant analytical development
TDM	:	Total dry matter
viz.,	:	Namely
WUE	:	Water use efficiency
Zn	:	Zinc

ABSTRACT

Name of the Author	:	**K. APARNA**
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The present investigation was aimed at evaluating the relative performance of ragi genotypes for physiological efficiency, drought tolerance, yield and grain quality attributes using various morpho-physiological and drought tolerance traits.

A field experiment was conducted during *Kharif*, 2015 at Agricultural Research station (Millets), ANGRAU, Tirupati. Field experiment was laid out in factorial randomized block design, replicated thrice with two main treatments i.e. adequately irrigated, rainfed and ten sub-treatments (genotypes). During the experiment a long dry spell for 20 days occurred i.e. from 47 DAS to 67 DAS, which has coincided with panicle initiation and flowering stages.

Growth and physiological traits viz. plant height, dry matter accumulation in different plant parts, leaf area index (LAI) and leaf area duration (LAD), WUE traits (SLA, SCMR) and other drought tolerance traits viz., chlorophyll stability index (CSI), relative water content (RWC) significantly reduced 1.7 per cent at 45 DAS and 0.3 per cent at 75 DAS under rainfed conditions compared to irrigated control. Similarly yield components viz., number of tillers plant^{-1}, number of fingers plant^{-1}, 1000 grain weight, straw yield, harvest index as well as grain yields were significantly reduced in rainfed treatment compared to control. However grain quality attributes viz., calcium, iron, protein and crude fiber contents did not vary significantly.

Among the genotypes, the three pre-release genotypes viz., BR-36, PPR-1012 and PPR-2773 recorded high physiological efficiency in terms of LAI, drymatter distribution, LAD and moderate SLA and high SCMR, CSI and RWC along with higher HI and yield under ranifed as well as irrigated conditions. It denotes their efficiency in performing under drought condition. PPR 2885, PPR-1044, PPR-1040, PR-10-30, Srichaitanya and Vakula recorded moderate drought tolerance with moderate yielding abilities. Hima (released variety) recorded low performance and it will not fit for cultivation in rainfed areas.

Grain quality attributes viz., Protein percent, Calcium, Iron and crude fiber contents were not significantly varied between treatments and genotypes.

The present study reveals that there is sufficient genotypic variability among ragi genotypes for growth, drought tolerance, yield and its attributes. Drought tolerance parameters viz., SCMR, chlorophyll stability index, relative water content, leaf proline content are reliable for screening ragi genotypes for drought tolerance. Leaf area duration is very useful physiological trait for identification of drought tolerant genotypes in ragi crop.

Chapter ~ I

Introduction

Chapter – I

INTRODUCTION

Ragi or fingermillet (*Eleusine coracana* (L.) Gaertn.), belongs to the family Poaceae, and subfamily Chloridoidae (Dida *et al*., 2007) with C_4 NAD-ME photosynthetic pathway (Ueno *et al*., 2006). The crop has high nutritional value and excellent storage qualities, hence, serves a famine reserve (Latha *et al*., 2005). It is an important nutritional cereal food crop extensively cultivated in the tropical and sub-tropical regions of India and Africa mainly by subsistence farmers to serve the regional food security (Kotschi, 2006). Current productivity of finger millet is distinctly superior compared to the major millets. It is an important small millet crop ranked third in India in area and production and has the pride of place in having the highest productivity among the millets after sorghum and pearlmillet (Saravanapandian *et al*., 2005). However, in the recent past, the yield of rainfed finger millet has reached a plateau (Anonymous, 2011), possibly due to regular occurrence of intermittent drought for a period of 30-35 days at one or the other crop growth stage. Further, it is also predicted that water deficit will continue to be a major abiotic factor affecting the global crop yields (Sharma and Lavanya, 2002).

The possibility of global climate change, effects on world food security in general and its regional impacts in particular have come to forefront of the scientific community. Crop growth, development, water use and yield under normal conditions are largely determined by weather.

Ragi is a versatile crop with high nutrient profile of protein (6-8%), fat (1.3%), calcium (296 mg), carbohydrate (70-76%), lysine (2.86%), tryptophan (1.39%) and methionine (2.86%). Ragi being an important millet crop in India, occupies an area of 1.268 Million hectares with an annual

production of 1.888 Million tonnes with an average productivity of 1.48 tonnes ha^{-1}. In Andhra Pradesh, it is cultivated in an area of 44,000 hectares with a production of 54,000 tonnes and a productivity of 1175 kg ha^{-1} (Indiastat.com, 2014-15).

Ragi is an important grain crop in the southern states of India. However, the yield levels achieved are below the actual yield potential because of poor management and kharif crop grown under rainfed conditions, which is prone to moisture stress at critical growth stages.

Drought, a complex combination of stresses, involves both moisture stress and high temperature stress. Water is one of the major environmental factors influencing almost all aspects, of plant growth and metabolism (Kramer, 1993).

Moisture stress during crop growth period especially in kharif growing season accounts for 70 per cent loss in productivity. Any effort to mitigate the loss due to drought could be useful to enhance the food production. It has been suggested that yield could be achieved more efficiently by identifying characteristics that allow a plant to escape, avoid or tolerate water stress. Better understanding of the morphological and physiological basis of changes under water stress resistance could aid into selection of varieties to obtain for a better performance (Singh, 1991).

Yield improvement over years in major cereals has been observed to be primarily due to improved harvest index in the varieties or selections and through both biomass and harvest index (Crosbie and Mock, 1981; Fischer and Edmeades, 2010). Physiological basis for such improved yield has been attributed to increased photosynthetic rates, crop growth rates, radiation use efficiency, Number of grains and harvest index (Fischer *et al*., 1998).

Grain yield is the product of harvest index (HI) and biomass. The Biomass or total dry matter (TDM) is found to be associated positively with leaf area index (LAI), leaf area duration (LAD) (Shankar *et al*., 1990; Anonymous, 2009).

High LAI would enable greater light interception and canopy photosynthesis. The LAI and Photosynthetic rate per unit leaf area, is inconsistent and variable with climatic fluctuations to a greater extent. Thus it is less studied and not much information is available in case of ragi. Further, ragi being a rainfed crop grown normally under intermittent moistures stress situations, higher leaf area would lead to more water loss through transpiration. It would be better to have high photosynthetic rate with lower leaf area so as to reduce the transpiration rate, increase water use efficiency and crop yield. The photosynthetic rate is dependent up on stomatal conductance, mesophyll conductance, carboxylation efficiency, light interception, and translocation efficiency. Therefore, physiological approaches are necessary to break yield plateau, as the grain yield is the product of biomass and harvest index.

The Present study was carried out to identify the ragi genotypes with following objectives,

Objectives

1. To study genotypic variation for moisture stress (rainfed) tolerance, yield and quality parameters.
2. To identify the plant traits associated with moisture stress tolerance in ragi.

Chapter ~ II

Review of Literature

Chapter – II

REVIEW OF LITERATURE

The available literature on water use efficiency traits, thermo-tolerance traits and yield attributes of ragi pertaining to the experiment entitled **"Identification of ragi genotypes for drought tolerance, high yield and seed quality parameters under *Kharif* rainfed conditions"** are reviewed here under. Plant growth and productivity of ragi is adversely affected by various biotic and abiotic stress factors. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield, Better understanding of the morphological and physiological basis of changes under water stress resistance could aid in to selection of varieties to obtain for a better performance. Information on drought induced effects on morphological, physiological yield and its associated traits in ragi is scanty.

Hence literature on cereals, legumes apart from millets are included under following categories viz., growth parameters, water use efficiency traits, drought tolerant traits, yield attributes and yield.

2.1 GROWTH PARAMETERS

The process of growth is dependent upon cell division and cell expansion which takes place under adequate moisture conditions. Hence plant growth and development is highly variable with genotype x environment interaction. Physiological efficiency of a genotype is determined by growth parameters like CGR, LAI, LAD, dry matter accumulation and harvest index (Chauhan *et al.*, 1996).

2.1.1 Plant Height (cm)

Rahman *et al.* (2002) during their studies on effect of water stress at different growth stages on yield and yield contributing characters of transplanted rice reported that moisture stress has decreased the plant height of rice cultivars. However, varietal response was different for most of the characters and had different degree of reduction. Among the four varieties (Binadhan4, shorn, Brridhan33, Binashail) Binashail have showed the highest plant height.

Sarvestani *et al.* (2008) reported that water stress at vegetative stage significantly reduced plant height in rice cultivars.

Razmjoo, *et al*., (2008) reported that water stress reduces plant growth in rice crop by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoting hormones.

Seghatoleslami *et al.* (2008) reported that water stress caused reduction in plant height of the three species of millets proso millet, foxtail millet and pearl millet.

Ameer Ahmed Mirbahar *et al.* (2009) during their studies on effect of water stress on yield and yield components of wheat reported that the water stress significantly reduced the plant height of all varieties.

Suzuki *et al*. (2015) summarized the specific impact of drought and heat on growth and development of cereals. Drought reduced plant height in wild barley, total number of spikes and seed weight, whereas heat stress (HS) affected pollen development, resulting in a lowered number of seeds per plant.

2.1.2 Leaf Area (cm^2 $plant^{-1}$)

Leaf area is important factor in determining the dry matter production and yield. Water stress reduces the leaf area, cell size and intercellular volume in rice crop (Kramer, 1969).

Alluwar and Deotale (1991) reported positive correlation between leaf area and yield and its importance in determining the yield. Assimilatory system might be a key factor for realization of grain yield (Gautam and Sharma, 1993).

Lilley and Fukai (1994) reported Marginal reduction in leaf area under water stress condition in rice varieties. Fukai and Cooper (1995) observed possible causes for drought affected leaf area development due to as reduced leaf expansion, leaf rolling and early senescence and suppressed tillering in rice.

Maqsood and Azam Ali (2007) during their studies on effects of environmental stress on growth, radiation use efficiency and yield of ragi reported that moisture stress reduced the leaf area of two finger millet land races TZM-01 and TZA-01.

Devi *et al.* (2013) reported that leaf area per plant in rice under aerobic conditions showed a gradual increase from 30 DAS to 75 DAS and then declined in all the aerobic rice cultivars. Among the tested rice cultivars NLR 3010 recorded significantly higher leaf area (606 cm^2 $plant^{-1}$).

2.1.3 Total Dry Matter

Dry matter accumulation and distribution is an important factor which indicates partitioning efficiency of photosynthetic assimilates. Soil moisture determines the distribution and accumulation of dry matter in different plant parts. Dry matter production under given environment is balance between photosynthesis and respiration which are dependent on of LAI, photosynthetic

capacity/unit area and LAR etc (Watson, 1958). During early stage of growth, dry matter production mainly depends on the development of the leaf area, while the later growing period is strongly influenced by the respiratory consumption.

Significant genotypic variation in dry matter accumulation have been reported in ragi and the extent of variation ranged from 67 to 489 g/ mrl (meter row length) in various studies (Ankegowda, 1996; Nagaraj and Mohankuamr, 2009; Anon, 2010).

Willmer and Flicker (1996) reported that reduction in dry matter production as a result of moisture stress is consistent with the general behavior of closure of stomata in finger millet crop.

Gifford *et al.* (1979) reported reduction in leaf expansion and in photosynthetic rate of rice are responsible for reduction in dry matter production and grain yield.

High dry matter production at flowering would lead to remobilization of photosynthates to reproductive structures and high biomass during post anthesis directly involved in enhancing the reproductive structures thus higher grain yield in (Chaudhuri, 1989). Highly positive correlations between TDM and grain yield has been documented in several crops (Gurumurthy, 1982, Waddington *et al*., 1986; Shankar, 1988; Anon, 2010).

The decrease of dry matter in later growth phases was attributed to senescence and drying of leaves in pearl millet (Kumbudini *et al.* 2001).

Maqsood and Azam Ali (2007) reported that total dry matter production was reduced under moisture stress condition in two finger millet land races TZA-01 and TZM-01. The difference in dry matter production between the irrigation treatments was 300 gm^{-2} and 200 gm^{-2} for TZA-01 and TZM-01 than drought exposed TZA-01 and TZM-01, respectively.

Sarvestani *et al.* (2008) reported that total biomass was reduced under water stress in all cultivars of rice. Water stress at vegetative stage effectively reduced total biomass due to decrease in photosynthetic rate and dry matter accumulation.

Moisture stress significantly decreased total dry matter of wheat genotypes under moisture stress conditions followed by Bulbul and Baviacora M 92. (Hafiz Muhammad Akram *et al.*, 2010). Moaed Almeselmani *et al.* (2012) also reported that the drought tolerant durum wheat varieties had higher total biomass under water stress conditions.

Devi *et al.* (2013) reported that NLR 3010 recorded significantly higher dry matter (555 kg m^{-2}) in rice under aerobic conditions followed by NLR 40059, NLR 33671 and NLR 34242. The cultivars NLR 40058 and NLR 30491 recorded lowest dry matter (404 and 425 g m^{-2}).

2.1.3.1 Leaves dry weight

The higher dry matter accumulation in leaves and its proper mobilization to sink during the crucial period of sink filling play a key role in determining the yield potential of a pearl millet genotype. The photosynthetic capacity of leaves becomes more crucial especially during the low light intensities Akiyamna *et al.* (1975). Generally thick leaves were found to be associated with higher photosynthetic rates and high SLW (Murata, 1961).

More dry matter yield in variety 86-M-56 and Sargodha Bajra 2011 may be due to more stem diameter, more number of leaves per plant and more leaf area per plant and more dry weight per plant in these varieties also reported significant difference among pearl millet varieties regarding dry matter yield (Mahmood U. Hassan, 2014).

Bakhuyzen and Van De (1996) reported that the higher leaves in wheat show a higher dry weight per cent is due to their higher dry weight

and lower moisture per unit leaf area. The dry weight per cent of every leaf increases throughout the life cycle. Before the flowering stage this is due to the fact that both dry weight and moisture increase, but the former increases more rapidly than the latter; after the flowering stage the moisture decreases while, the dry weight continues to increase. The dry weight per cent increases or that the moisture per cent. decreases at the time of flowering does not, however, show whether this is due to a sudden increase in dry weight alone, or to an increase both in dry weight and moisture, the latter increasing less rapidly than the former, or to a sudden loss of water whether or not accompanied by an increase or decrease in dry weight. The only way to find the real cause of this change in moisture per cent is to consider the absolute dry weight and moisture. We find then that the moisture of the stems and leaves increases until the time of flowering but decreases markedly just after flowering.

2.1.3.2 Shoot dry weight

Mostajeran and Rohimi-Eichi (2009) reported that a decrease in shoot dry matter under lower soil moisture might be due to reduction of leaf area and photosynthetic rate. Retention of green leaves under drought conditions has been used as a selection criterion for drought resistance.

Mohammedkhani and Heidari (2008) reported that upland rice varieties displayed significant reduction in shoot dry weight at the most drought levels as compared of control. This reduction in growth might be due to low osmotic potential as well as a decrease in wall extensibility and cellular expansion.

2.1.3.3 Root dry weight

Root of wheat grown in dry conditions is more branched and finer than those under adequate moisture conditions (Kmoch *et al.* 1957). According to Slayter, (1973) two types of effects of water deficit on root

development can be observed, first is reduction in rate of meristmetic activity and root elongation directly associated with the level of internal water deficit and second effect of suberization on the water and nutrients uptake proportional of the root system as whole. High dry weight under water stress conditions is a desirable characteristic for survivability of the rice plant under water stress condition.

Acceleration of root growth under moisture stress has been observed. The increase observed in root weight under moisture stress indicate greater density of root and or greater depths of root penetration, both of these are important morphological adaptations to moisture deficit and results in greater extraction of soil water (Hoogenboom *et al.* 1987).

2.2 PHYSIOLOGICAL ATTRIBUTES

2.2.1 Leaf Area Index (LAI)

Leaf Area Index (LAI) is an important plant factor in determining the dry matter accumulation and hence the crop yield. The LAI was directly related to grain yield irrespective of the variety in wheat and maintenance of high LAI at anthesis would be desirable for obtaining higher yield in the stressed plants

Having realized the importance of LAI, several investigations were initiated to assess genetic variability in parameters associated with leaf area of finger millet crop. Vishwanath (1977) reported a range of LAI from 2.78 to 5.06 among four varieties, and variety PR-202 recorded highest LAI of 5.06 followed by Purna, HPB-7-6 and HR-374. Chandrasekhar (1978) showed that, variety, HPB-7-6 had higher LAI (4.08) and LAD (274.1 days) compared to HR-374 at 83 days after planting (DAP). The higher LAI in HPB-7-6 at tillering stage resulted in high biomass production (Reddy and Patil, 1982).

Rapid canopy development during early stages of crop is an important pre-requisite to achieve early establishment and crop growth, which is a constraint in case of finger millet. Canopy development is nothing but increase in leaf area that determines the LAI. The LAI increases up to flowering and thereafter decreases. The rate of increase is maximum between 30th and 45th day after transplanting (Subramaniam, 1980). With increase in leaf area, the extent to light interception increases and hence, a positive significant relationship exists between leaf area and total biomass (Vasanth Kumar, 1975; Chandrasekhar, 1978; Gurumurthy, 1982; Shankar, 1988; Ankegowda, 1996).

Moisture stress induced changes in leaf area was also noticed in LAI, which varied with different moisture levels duly reflecting in the biomass yield. Wang *et al.* (2003) reported a decline in LAI of rice varieties due to moisture stress and the pattern of variation in physiological parameters at different growth stages in seven improved upland cultivars was compared with traditional upland cultivar.

Maqsood and Azam Ali (2007) reported that leaf area index LAI was reduced under moisture stress condition in two finger millet land races TZA-01and TZM-01. LAI for irrigated TZA-01 and TZM-01 continued to increase and reached maximum values. The minimum LAI value was recorded in drought exposed TZA-01 and TZM-01 at 105 DAS.

Devi *et al.* (2013) reported that among rice genotypes under aerobic method of cultivation, NLR 3010 recorded significantly highest LAI (2.71) at flowering stage NLR 30491 recorded least LAI. The decrease in the leaf area index towards maturity may be due to lesser number of leaves as a result of senescence in old leaves.

LAI increased upto 45 DAS and declined thereafter in ragi genotypes. moisture stress at panicle initiation stage i.e., from 35-60 DAS decreased mean LAI significantly (Venkatesh Babu *et al.*, 2015).

2.2.2 Leaf Area Duration (LAD)

Krishnasastry *et al.* (1981) during their studies on desirable plant characteristics of genotypes of finger millet for rainfed conditions reported that moisture stress reduced the LAD of the seven varieties.

Chetti and Sirohi (1995) revealed that LAD as useful growth parameter indicating the efficiency of photosynthetic system, with high degree of association with dry matter accumulation.

Leaf area duration also represents ‘stay greenness’ of leaves, which is key factor during grain filling stage in cereals. Leaf area duration which measures the ability of the plant to produce and maintain leaf area, also increased with the advancement of crop age being maximum at 45 days after rice emergence (Chauhan *et al.*, 1996).

Wuwen Ge *et al.* (2008) was suggested that LAD might be used to better explain the advantage in the dry matter production of super hybrid rice than Leaf area index.

Devi *et al.* (2013) reported rice genotype NLR 3010 showed significantly higher LAD values and high yield as compared to all other entries under aerobic method of cultivation high LAD was reported in ragi genotypes GP-153 and GP-111 which also maintained high LAI under moisture stress conditions (Venkatesh Babu *et al.*, 2014).

2.3 DROUGHT TOLERANT TRAITS

2.3.1 Water Use Efficiency Traits

Water use efficiency has been proved to be an important trait particularly in adverse environmental conditions. The genotypes maintaining higher WUE have an efficient stomatal regulatory capacity (Maroco *et al.,* 1997). The long-term structural and growth adjustments as well as changes in intrinsic WUE are important mechanisms of *Acacia Koa* to withstand water limitation (Ares and Fownes 1999). Measurement of WUE might be a useful trait for selecting genotypes with improved drought adaptation and biomass productivity under different environmental conditions. The instantaneous WUE is estimated as the ratio of net photosynthetic rate to transpiration. Higher the values better the efficiency of the plant to divert water for photosynthesis than transpiration Petite *et al.* (2000).

The water use efficiency (WUE) ability of the plant to produce dry matter/unit of water is a genotypic character and two important physiological traits that determine the variability in WUE are photosynthetic rate (Pn) and transpiration rate (Tr) are basically the function of leaf (Singh *et al.* 2008). The genotypes did not suffer due to moisture stress and attained high water use efficiency due to high productivity probably by allocation of greater proportion of assimilates to grains. To improve grain yield of crops in rainfed areas, one must increase the water use efficiency by decreasing transpiration and/or increase the proportion of dry matter allocation to grains (Kumar *et al.,* 2010).

The best way to conserve soil water is to select plant genotypes having higher WUE so that the transpiration water loss can be optimized. Such genotypes should also be able to tolerate drought stress (Kannan *et al.,* 2010). The pearl millet genotype IVTPM 2 (4.11) indicated the lowest water use efficiency indicating its unsuitability for drought prone areas.

Several studies have identified indirect surrogate measurements, specific leaf area (SLA) and SPAD (Soil Plant Analytical Development) chlorophyll meter reading (SCMR) which are associated with WUE (Wright *et al.*, 1994; Reddy *et al.*, 2003).

2.3.1.1 Specific leaf area (SLA) (cm^2 g^{-1})

SLA is one of the physiological traits in plant growth analysis and is the ratio of leaf area to its dry weight. The SLA is often considered as an indirect measure of leaf expansion. The SLA was negatively related to WUE and was positively related to harvest Index, suggesting that selection for low SLA might result in the production of more dry matter with minimal influence on pod weight (Wright *et al.*, 1993).

Higher SLA means higher leaf area per unit biomass and a larger surface area for transpiration. On the other hand, if SLA is higher, the leaf thickness would be less and hence the capacity of photosynthesis would be smaller. Since transpiration and photosynthetic capacity determine the variability in TE, an inverse relationship between SLA and WUE is normally observed (Wright *et al.*, 1994).

Bindhu Madhava *et al.* (2002) provided evidence that the relationship between WUE and SLA was predominantly due to a strong association between SLA and specific leaf nitrogen (SLN), which has strong positive linkage with SCMR. Talwar *et al.* (2004) and Latha and Reddy (2007) also reported a significant genotypic difference for SLA in groundnut genotypes

Babitha *et al.* (2006) reported that the groundnut Spanish genotype JAL-07 had lower SLA (101.6 cm^2) and high SCMR (52) indicating that it can tolerate both water deficit and high temperature.

Venkatesh Babu *et al.* (2015) reported that there is a significant decrease in SLA values with moisture stress in all ragi genotypes. They also opined that low SLA and high SCMR are good indicates of high WUE.

2.3.1.2 SCMR (Soil plant analytical development (SPAD) chlorophyll meter readings)

The chlorophyll meter or SPAD meter is a simple portable diagnostic tool that can measure the greenness or relative chlorophyll content of leaves (Inada, 1985 and Karyia *et al.*, 1982).

Jiang and Vergara (1986) reported that a significant positive correlation of (R^2=0.989) was obtained between the SPAD readings and chlorophyll content. Apart from positive correlation between SPAD and chlorophyll content, several physiologist explored SCMR values for correlating with WUE. Wright *et al.* (1993) suggested SCMR can be used as surrogate method to measure WUE. Water stress decreased chlorophyll content in rice leaves (Zhu and Huang, 1994; Peng and Bouman, 2007).

The reports show the different responses of chlorophyll of drought-resistant and sensitive cultivars to drought show that drought stress does not affect chlorophyll concentration in tolerant types (Kulshreshta *et al*., 1987). The resistant genotypes of wheat had higher chlorophyll content than sensitive ones under the oxidative stress (Sairam *et al*., 2002). Higher chlorophyll content during post-anthesis stage results in superior yield and yield components (Almeselmani *et al*., 2013).

Chlorophyll content was positively correlated to biomass and grain weight (Del Blanco *et al.*, 2000). Chlorophyll content negatively correlated with specific leaf area and positively with photosynthetic rates in groundnut (Nageswara rao *et al*., 2001). Drought results in the reduction of leaf greenness in finger millet (Majumdar *et al*., 1991).

Reddy *et al.* (2003) reported significant negative correlation between SCMR and SLA, while the correlation between SCMR and total chlorophyll content and SCMR and seed yield were positive in groundnut genotypes. Genotypes with high SCMR had greater photosynthetic capacity and thereby

assimilated more carbon per unit land area, which might have influenced seed yield (Latha, 2004).Sudhakar *et al.* (2006) also reported significant positive correlation between SCMR and yield under terminal moisture stress conditions in greengram and blackgram.

Muhammad Maqsood and Azam Ali (2007) reported that SPAD reading were reduced under moisture stress condition in two finger millet land races TZA-01 and TZM-01. The minimum leaf greeness value or SPAD (29) was recorded in droughted TZA-01 as compared to irrigated TZM-01(42).

There is significant increase in SCMR values with moisture stress in all genotypes (Devi *et al.*, 2013). GP-111 and GP-104 genotypes which maintained high SCMR, RWC and low SLA also maintained higher yield under moisture stress conditions.

2.3.2 Other Drought Tolerant Traits

2.3.2.1 Cholrophyll Stability Index (CSI)

Improvement in high temperature tolerance is considered vital for yield improvement in many regions and cropping systems. The potential of a genotype or species to acclimate to moderately high temperature, thereby reducing high temperature injury is an important factor in determining plant performance in high temperature environments.

Schreiber and Berry (1977) considered the thermo-stability of photosynthetic apparatus as being an important determinant of heat tolerance. Martineau *et al.* (1979) observed the genotypic differences in heat tolerance have been determined by the use of conductivity measurements.

A significant relationship was found with performance in high temperature environments in several crops, such as sorghum (Sullivan and Ross, 1979), soybean (Martineau *et al.*, 1979) and groundnut (Talwar *et al.*, 2004).

The sensitivity of rice to high temperature varies with growth phase, an increase in day/night temperature, and genotype (Yoshida, 1981 and Peng *et al.*, 2004). The unusual rise in soil or atmospheric temperature during different growth phases differentially affects rice growth and productivity.

Talwar *et al.* (1999), has been reported the genotypic variation for WUE and high temperature tolerance. The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the rice crop by affecting its phenology, physiology, and yield components (Peng *et al.*, 2004 and Singh, 2009).

Genotypic variation for WUE traits has been reported in diverse groundnut genotypes (Reddy *et al.*, 2003 and Nautiyal *et al.*, 2004). This shows the possibility of selection of superior genotypes under water stress and high temperature environments.

2.3.2.2 Relative Water Content (RWC)

RWC is one of the measures which give an idea of tissue water status. The mechanism of controlling plant water status may involve water uptake or water conservation by the plant and also internal plant water conductance during drought and the plant water status can differ significantly among cultivars exposed to the same period of water exclusion (O'Toole and Moya, 1978).

The RWC is an important trait for selection of genotypes against the drought conditions. The plants having higher RWC can withstand adverse environmental conditions. The water stress is known to decrease leaf water potential and RWC in different crops including pearl millet (Subramanian *et al.* 1989). The plants under water stress and were accompanied by change in RWC indicating a higher or lower osmo-regulation depending upon the magnitude of the decrease. Decreased water potential of the leaf under stress

may be due to decreased availability /absorption and translocation of water from soil and roots and ultimately to leaves (Maribona *et al.* 1992).

Maintenance of higher RWC under water-stress conditions as a tolerance mechanism is generally due to high stomatal resistance that caused by osmotic adjustment or reduction in transpiration (Schonfeld *et al*., 1988). Therefore, osmo-regulation would help in cell development/ cell volume and plant growth under water stress conditions. Further, Shamsi (2010) reported that the differences in the RWC between wheat cultivars under drought stress may be due to the differences in their ability to absorb water from soil or the ability of the stomata to reduce the loss of water.

The genotypes maintaining higher relative water content accumulates solutes and had higher photosynthesis. Relative water content (%) in leaf tissue decreased in all the rice genotypes under moisture deficit conditions (Nadarajan and Kumaravelu, 1993).

Leaf RWC is proposed as more important indicator of water status than other water potential parameters under drought stress conditions. During plant development, drought stress significantly reduced RWC values (Siddique *et al.*, 2000 and Islam *et al.*, 1994).

Enhanced RWC helped the plants to perform the physiological processes like stomatal conductance, photosynthesis, transpiration and biochemical metabolism more effectively even under low moisture condition (Rekika *et al.*, 2000).

Maintenance of plant water status is more important for plant functions, which controls crop performance under drought. Leaf water potential is closely related to leaf RWC, but it is confounded by osmotic adjustment, stronger correlations might be found between yield and RWC under water stress conditions (Lafitte, 2002).

RWC was strongly associated with grain yield under rainfed condition. This indicates that maintenance of higher water status under drought plays an important role in producing grain yield (Ravindra Kumar *et al.,* 2004). It implies that well developed root system helps in maintaining higher water status.

Reduction in RWC (2.58%) found to decrease the stomatal conductance (21.7%), transpiration rate (25.3%) and photosynthetic rate (16.8%) in finger millet (Reddy *et al*., 2010). RWC under stress found to be positively associated with water use efficiency and biomass production (Balouchi, 2010). A decrease in RWC under stress found to accelerate flag leaf senescence and grain-filling period, resulting in decreased yield and yield attributes (Lilley and Ludlow, 1996; Almeselmani *et al.,* 2011). Therefore, quantification of RWC under stress condition can be appropriately used as a physiological trait in identification of drought tolerant genotypes.

Aziz *et al.* (2011) during their studies on the drought tolerance of screening of wheat varieties by inducing water stress conditions revealed that the superior variety Hasim-8 has maintained high RWC and high stress tolerance index.

Sunitha Gupta *et al.* (2012) reported that the reduction in RWC and membrane stability index was significantly higher in drought sensitive wheat genotype HD-2329 under water stress conditions. Similarly Moaed Almeselmani *et al* (2012) reported that highest value of RWC was recorded in the drought tolerant durum wheat varieties compared to others at vegetative and anthesis stage under rainfed conditions.

Akram *et al.* (2013) reported that water deficit at all the three growth stages in three rice cultivars hampered relative water content (RWC) of plant leaves significantly. Thus, the maximum decrease in RWC (35.16%) was noted in case of drought stress at panicle initiation which was followed

by anthesis and grainfilling with the decrease of 26.22 and 17.03 per cent respectively.

RWC indicate the water status of the cells and have significant association with yield and stress tolerance. Significant difference in RWC among genotypes under irrigated and moisture stress conditions were reported among ragi genotypes (Venkatesh Babu *et al.*, 2015).

2.3.2.3 Root length (cm)

Narayan and Mishra (1989) recorded deeper penetration of root under moisture stress, and concluded that depth of root penetration can provide a useful selection criterion for wheat breeding under drought stress. Root intensity (visible root length/cm^2 viewing surface) gave an indication of distribution of total root length which could serve as an important selection criterion for screening cultivars for drought resistance.

Boyer, (1996) identified deep root system as the targeted for drought tolerance improvement .Production of root system under drought is very important and had good correlation with yield under moisture stress (Darofeev and Tyselano, 1982). Furthermore, drought stress caused pronounced changes in root structure such as increased branching and density (Eghball and Maranville, 1993). Cultivars having deep and thick roots are good for drought stress condition and are positively correlated with xylem vessel area, which are vital to the conductance of water from soil to the upper parts of the rice plants to meet the evaporative demand.

2.3.2.4 Proline content (µg g^{-1})

Maiti *et al.* (2000) reported that in groundnut, proline accumulation is a mechanism for plants adaptation to abiotic stress conditions like drought. Other roles for proline have been proposed, including stabilization of macromolecules, a sink for excess reductant and a store of carbon and

nitrogen for use after relief of water deficit. Yang *et al*. (2001) found that highly drought resistance plants reduce their water loss by increasing proline content.

Accumulation of proline has been advocated as a parameter of selection for stress tolerance. Proline accumulation can be met with the moisture stress. High levels of proline enabled the plant to maintain low water potentials. Plants are known to withstand the prevailing drought stress by synthesizing and accumulating compatible solutes like sugars, polyols, betaines and proline which play a pivotal role in stress tolerance (Ramanjulu and Bartels, 2002). Proline accumulation is often considered to be involved in stress resistance mechanisms (Ramanjulu and Sudhakar, 2000). Proline accumulated in plants as a response of various environmental stresses (Upadhyaya *et al*., 2008).

Under water stress conditions, the proline content showed highest and positively correlated with shoot length ($r = 0.8943$, $p<0.01$), root length ($r = 0.8394$, $p<0.01$) and POD ($r = 0.8715$, $p<0.01$). Accumulation of proline content under water stress indicates that accumulated proline might act as a compatible solute regulating and reducing water loss from the plant cell during water deficit (Yokota *et al*., 2006) and play important role in osmosis balance (Fedina *et al*., 2002). Proline accumulates under stress also supplies energy for survival and growth and thereby helps the plants to tolerate stress condition (Kumar *et al*., 2011).Thus, the proline content is a good indicator for screening drought tolerant varieties in water stress condition (Bayoumi *et al*., 2008; Kumar *et al*., 2011).

During the stress conditions proline amino acid accumulates in the plant causing stomatal closure which prevents further water loss (Sumesh *et al.*, 2008). An increase in proline content by water stress has been suggested as a test of resistance to water stress Palfi and Juhasz, (1971). The proline

accumulation in water stress leaves might provide a source of respiratory energy to the recovering plant (Ebercon, 1976).

Gupta *et al*., (2013) reported that in mothbean to avoid water loss under stress, plants accumulate compatible solutes such as proline which act as low-molecular weight chaperones. Genotypic variations for increase in proline level due to stress have been known earlier in sunflower (Amutha *et al*., 2007).

Nisha Kataria *et al*. (2014) reported that in mungbean under stress condition, the decrease in osmotic potential was mainly due to the accumulation of solutes like proline and soluble carbohydrates. Potassium application improves physiological characteristics such as stomatal resistance, RWC, and proline contents which might improve the overall plant water status and metabolism in groundnut under water stress condition (Umar *et al*., 1990).

Gosavi (2014) reported that proline is accumulated as an osmoprotectant of cellular structures in response to osmotic stress in sorghum. Highest proline content under controlled condition was observed in genotype IS-18872 (0.73 molg fw), while the lowest proline content was recorded in SPV-1704 (0.09 molg fw) increase in accumulation of proline was observed in sorghum seedlings of all the genotypes subjected to heat stress.

2.4 YIELD ATTRIBUTES

Though grain yield is the product of biomass and harvest index, the yield attributing traits indirectly contributes to either biomass or HI and determines the grain yield.

Large genotypic variations in yield of finger millet crop from 1.58 t/ha to the extent of 6.10 t/ha have been reported by considering several

investigations with different sets of varieties (Patnaik, 1968; Rajashekara *et al*., 1972; Vishwanath, 1977; Ashok *et al*., 1979; Gurumurthy, 1982; Ankegowda, 1996; Nagaraj and Mohankumar, 2009; Anon, 2009 and 2010).

The stress factors especially, negatively affect plant growth and development and causes a sharp decrease of plants productivity (Pan *et al.* 2002).

2.4.1 Number of Tillers per Plant

The productive tillers are very important in deciding grain yield that varies from 1 to 5 per plant and has direct correlation with grain yield in the improved varieties (Chandrasekhar, 1978; Gurumurthy, 1982; Nagaraj and Mohankumar, 2009). The total number of tillers that include unproductive tillers also has a negative relationship with grain yield in finger millet crop (Udayakumar *et al*., 1986).

Negative correlations between grain yield and number of basal tillers (Dhagat *et al*., 1973) and total number of tillers in finger millet crop (Udaykumar *et al*., 1986) is also documented. Mahadevappa and Ponnaiya (1962) reported that in finger millet contribution to yield by tillers is estimated to be 37 per cent. Accordingly it would imply that the number of ears per unit area is another important yield attribute.

2.4.2 Number of Fingers per Plant

The number of ear heads per unit area shown to be positively associated with grain yield (Vasanthakumar, 1975). Mean ear head weight contributes to a greater extent than any other yield attributing traits and highly correlated to grain yield (Dhagat *et al*., 1973). Number of fingers in an ear head also positively correlated to grain yield (Rajasekhar *et al*., 1971) and test weight (Vasanthkumar, 1975; Anon, 2010).

2.4.3 Grain Yield (kg ha^{-1})

Dey and Upadhyaya, (1996) suggested three different critical stages of growth – seedling, vegetative and anthesis, which are highly affected by water stress and reduces the estimates of component characters finally grain yield.

Due to imposition of moisture stress from panicle initiation to grain filling stage grain yield was significantly reduced compared to irrigated control. The possible decrease in stomatal conductance and leaf area resulting in loss of dry matter accumulation partly explains the decrease in yield and yield components under moisture stress (Ramana Rao, 1994).

Due to imposition of moisture stress from panicle initiation to grain filling stage, mean grain yield was significantly decreased to the extent of 37.09 per cent. Similar results of reduction of grain yield under moisture stress conditions was reported in ragi by Maqsood and Azam Ali (2007).

Grain yield per plot also showed positive correlation with 1000-seed weight (Nadini *et al*. 2010), thus suggesting that any positive improvement on these traits will subsequently give positive results for grain yield. Grain yield per plot showed highly significant negative correlation with days to flowering (-0.32). Similarly, Bezawelataw *et al.* (2006) and Wolie and Dessalegen (2011), found finger millet grain yield to be negatively significantly correlated with days to flowering.

Venkatesh Babu *et al.* (2015) reported that moisture stress affected grain yield in ragi and GP-111 genotypes which maintained high WUE and physiological efficiency recorded higher grain yield.

2.4.4 Harvest Index (HI)

The term HI proposed by Donald (1979) is the ratio of the grain yield to the aerial parts of the biological yield expressed in percentage. Grain yield could be conveniently expressed as, product of biological yield X HI,

suggesting that yield can be increased either through increase in biological yield or HI. In many cereals the yield improvement was through the increased HI (Austin *et al*., 1980; Fischer and Edmeades, 2010).

HI could be increased from 0.30 to 0.45 in 15 cycles of selection by reducing plant height in wheat without any change in biomass production at an optimum plant density (Johnson *et al*., 1986). HI was also found to improve due to increased threshing per cent (Shankar, 1988), by decreasing the husk content and also by partitioning of biomass towards reproductive structures (Belford and Sedgley, 1991) such as number of seeds, seed size and ear head weight.

Harvest index was highest in GP-111 ragi genotypes, when exposed to moisture stress conditions. It represents increased physiological capacity to mobilize photosynthates and translocate them efficiently to organs of economic values in grain yield (Venkatesh Babu *et al.*, 2015).

2.5 QUALITY PARAMETERS

2.5.1 Calicum Content (%)

The average calcium content of ragi is 416.86 mg/100 g Joseph and Garesan (1998) reported that calcium content of 36 genotypes of finger millet ranged from 162 to 487 mg/100 g. Singh and Raghuvanshni (2012), reported that ragi has the highest calcium content among all cereals (344 mg/100g).

They also reported that the ragi is a good source of nutrients especially of calcium, other minerals and fiber. The mineral composition of millet grains is highly variable. The genetic factors and environmental conditions prevailing affect the mineral content of these food grains.

2.5.2 Iron Content (%)

Seeds are rich in iron containing 46 mg kg^{-1} (Serna and Saldivar and Rooney 1995) which is much higher than wheat and rice. Ragi is a good source of α and β amylases (Chandrasekhara and Swaminatan 1953) and malted millet is extensively used in weaning food, infant food and supplementary food formulations.

2.5.3 Protein Content (%)

Davies (1987) reported that soluble protein decreased significantly in chickpea at both vegetative and flowering stages when they were imposed to drought stress. Plants stressed at the vegetative stage, gave significantly higher protein levels than plants stressed during anthesis or during both the vegetative and anthesis. Protein degradation might be the result of increased activity of protease or other catabolic enzymes, which were activated under drought stress. A decrease in the protein concentration would be a typical symptom of oxidative stress and has frequently been observed in drought stressed plants (Seel *et al.*, 1992; Moran *et al.*, 1994).

Baruah *et al.* (2012) reported that total protein content decreases due to abiotic stress. As synthesis of proteins occur during dehydration stress a class of proteins called late embryo-genesis abundant (LAE) globular protein known as osmotin or dehydrin are known to accumulate in dry seeds, which play an important role in the regulation of dehy-dration in seeds. In the present study the results obtained with higher protein content in *Borah*, *Beriabhanga*, *Laodubi and Solpuna* are in agreement with the findings of Chinoy *et al.* (2012) who also reported a high protein content in drought stressed rice plant.

2.5.4 Fiber Content (%)

Malleshi and Hadimani (1993) reported that ragi can add substantial value to the diet in terms of protein and carbohydrates which is comparable to other cereals. In addition, it contributes vitamins, minerals and fiber as it is consumed whole in comparison to rice which is usually consumed after mailling and polishing.

Chapter ~ III

Material and Methods

Chapter – III

MATERIAL AND METHODS

The details of materials and methods adopted in present investigation on **"Identification of ragi genotypes for drought tolerance, high yield and seed quality parameters under *Kharif* rainfed conditions"** are briefly described in this chapter.

3.1 LOCATION OF EXPERIMENT SITE

The present field experiment was conducted at Agricultural research station (millets), Perumallapalli, Tirupati during *Kharif*, 2015 which is geographically situated at 13°N latitude and 79°E Longitude with an of 182.9 m above mean sea level in the southern agro-climatic zone of Andhra Pradesh.

3.2 DETAILS OF EXPERIMENTAL SITE

The experiment was conducted on sandy clay loam. The field was uniform in level and fertility. Soil samples were drawn at random from 0 to 30 cm soil depth from the experimental field and composite samples were analyzed for various physico-chemical properties.

3.2.1 Soil Characteristics

Soil samples were drawn at random from 0 to 15 and 15 to 30 cm depth from the experimental field. The composite soil samples were analyzed for various physico-chemical properties and the results are presented in the following Table 3.1.

Chemical analysis of soil samples indicated that the soil is neutral in reaction, low in organic matter, available nitrogen and phosphorus and high in available potassium.

Table 3.1. Physico-chemical properties of soil of the experimental field

Particulars	Soil depth (cm)	Method adopted
	0-30 cm	
I. Physical characteristics		
Coarse sand (%)	37.55	Bouyoucos Hydrometer (Piper, 1950)
Fine sand (%)	28.56	
Silt (%)	7.90	
Clay (%)	28.55	
Soil texture	Sandy Loam	
II. Chemical characteristics		
Soil pH (1.0: 2.5 soil water suspension)	7.16	Glass electrode pH meter (Jackson, 1973)
Electrical Conductivity (dS m^{-1})	0.208	Conductivity bridge (Jackson, 1973)
Organic carbon (%)	0.47	Wet digestion method (Walkley and Black, 1934)
Available N (kg ha^{-1})	205	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	16.23	Olsen's method (Olsen *et al*., 1954)
Available K_2O (kg ha^{-1})	235	Flame photometry (Jackson, 1973)

3.3 METEOROLOGICAL DATA

Direct sowing of ragi seeds was done on August, 29 2015 along with fertilizer application. The overall meteorological situations (standard week wise) during the experiment period is presented in Table 3.2 and Fig. 3.1 and discussed here under.

3.3.1 Rainfall

During the crop period, the weekly mean rainfall ranged from 4.0 to 266.9 mm day^{-1} with an average of 78.33 mm day^{-1}. A total of 1174.3 mm of rainfall was received in total crop period from 28-8-2015 to 13-12-2015. A dry spell of 20 days from 15-10-2015 to 04-11-2015 was occurred during the experiment.

3.3.2 Temperature

The weekly mean maximum temperature during the crop period ranged from 26.3°C to 34.5°C, with an average of 31.10°C. The weekly mean minimum temperature during the crop growth period varied from 18.6°C to 23.5°C, with an average of 21.64°C.

3.3.3 Sunshine Hours

The weekly mean bright sunshine hour's day^{-1} during the crop growth period ranged from 0.7 to 8.1 hours day^{-1} with an average of 4.58 hours day^{-1}.

3.3.4 Relative Humidity

The weekly mean relative humidity during the crop growth period ranged from 64.6 to 87.30 per cent, with an average of 74.18 per cent.

3.3.5 Mean Evaporation

During the crop period, the weekly mean evaporation (USWB Class-A Open pan evaporimeter) ranged from 3.0 to 5.7 mm day^{-1}, with an average of 4.33 mm day^{-1}.

Table 3.2. Standard week wise mean meteorological data during the crop growth period (29-08-2015 to 10-12-2015)

Standard week	Date and month	Temperature (°C)				Mean relative humidity (%)		Rainfall (mm)		Number of rainy days		Mean evaporation (mm day^{-1})		Mean bright sunshine (hours day^{-1})	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
35	27 Aug – 02 Sept	34.5	1.36	23.5	-0.81	68.5	3.47	9.0	-26.2	1	-0.7	5.7	0.65	4.5	0.17
36	03 Sep – 09 Sept	31.9	-1.59	22.1	-2.37	65.0	-0.25	97.2	62.8	3	1.1	4.7	-0.07	3.9	-0.22
37	10 Sept – 16 Sept	31.3	-2.16	22.5	-1.63	73.65	7.64	0	-31.08	0	-2	4.4	-0.81	4.4	-0.47
38	17 Sept – 23 Sept	33.9	0.56	21.3	-3.01	64.6	1.055	32	16.54	2	1	4.3	-1.16	4.7	-0.11
39	24 Sept – 30 Sept	34.0	0.02	20.7	-3.6	67.85	3.33	69	44.15	3	1.6	5.1	-0.09	6.3	0.33
40	01 Oct – 07 Oct	30.9	-2.83	18.6	-5.59	68.45	3.515	51	33.43	4	3.1	4.2	-0.49	5	-0.58
41	08 Oct – 14 Oct	33.0	-0.36	20.7	-2.36	71.8	4.665	114.2	88.6	4	2.4	4.1	-0.31	3.4	-2.11
42	15 Oct – 21 Oct	33.9	1.11	23.2	0.68	64.95	-6.235	0	-31.91	0	-2	5	0.78	8.1	2.56
43	22 Oct – 28 Oct	32.5	1.56	21.0	-1.15	71.45	-3.335	0	-67.91	0	-3.5	4.7	1.16	7.2	3.21
44	29 Oct – 04 Nov	31.6	1.26	23.1	1.39	79.95	3.605	4	-40.10	0	0.1	4.4	1.15	3.9	-0.58
45	05 Nov – 11 Nov	29.6	-0.57	22.9	1.98	83.15	9.04	210	179.24	4	2.6	4	0.49	4.3	-1.06
46	12 Nov – 18 Nov	26.3	-3.48	21.3	1.57	86.7	14.9	266.9	243.58	5	3.6	3.7	-0.15	0.7	-5.23
47	19 Nov – 25 Nov	27.4	-2.59	21.9	1.75	87.3	14.035	170	123	6	4.2	3	-0.52	2.1	-3.52
48	26 Nov – 02 Dec	28.4	-0.69	20.9	1.17	81	7.14	144.6	95.84	3	1.5	4	0.35	5.1	0.35
49	03 Dec – 09 Dec	28.5	0.18	22.1	2.63	75.45	1.185	6.4	-38.14	1	-0.4	4.3	1.04	4.3	-0.56
50	10 Dec – 16 Dec	30.0	0.93	20.5	0.94	77.1	3.26	0	-15.39	0	-1	3.8	0.55	5.4	0.57

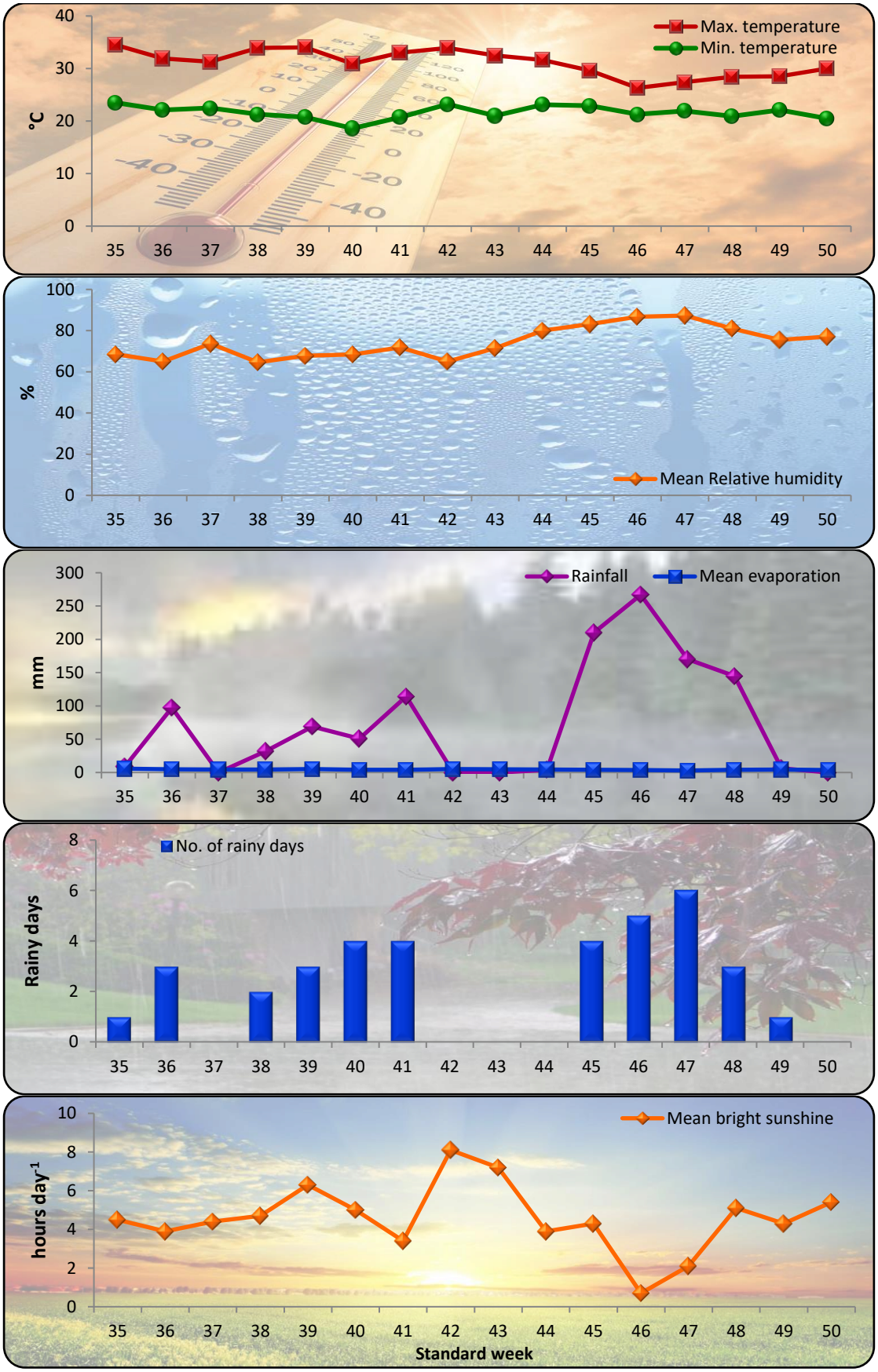


Fig 3.1. Standard week wise meteorological data during the crop growth period (29-08-2015 to 10-12-2015)

3.4 EXPERIMENTAL DETAILS

3.4.1 Design and Layout

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with ten treatments and replicated thrice as per the details given below. The details of layout plan are given in Fig. 3.2.

3.4.2 Treatments

Effect on plant growth and development of ragi was studied strictly under rainfed condition with following treatments.

3.4.3 Main Treatments

T_1 : Irrigated (Control) Three irrigations provided at 10 days interval.

T_2 : Rainfed (No irrigation provided except life saving irrigation at sowing)

3.4.4 Sub Treatments

Ten genotypes (Obtained from Agricultural Research Station, Perumallapalli ANGRAU, A.P)

Pre-release genotypes		Released genotypes
G_1 : PPR-1012	G_5: PPR-1044	G_8 : Sri chaitanya
G_2: PPR-2885	G_6: PPR-1040	G_9 : Vakula
G_3: PPR-2773	G_7: PR-10-30	G_{10} : Hima
G_4: BR-36		

3.5 CULTIVATION DETAILS

3.5.1 Preparatory Cultivation

The experimental field was ploughed twice with tractor drawn cultivator followed by bullock drawn blade harrow. The field was properly leveled with leveling plank and the experimental field was provided with two irrigations and drainage channels.

Irrigation channel	R_1		R_2		R_3		Irrigation channel
	G_1T_1	G_4T_2	G_7T_2	G_1T_1	G_4T_1	G_7T_2	
	G_5T_1	G_2T_2	G_8T_2	G_5T_1	G_2T_1	G_8T_2	
	G_9T_1	G_7T_2	G_1T_2	G_9T_1	G_7T_1	G_1T_2	
	G_2T_1	$G_{10}T_2$	G_9T_2	G_2T_1	$G_{10}T_1$	G_9T_2	
	G_6T_1	G_3T_2	G_6T_2	G_6T_1	G_3T_1	G_6T_2	
	G_8T_1	G_9T_2	G_5T_2	G_8T_1	G_9T_1	G_5T_2	
	$G_{10}T_1$	G_5T_2	G_4T_2	$G_{10}T_1$	G_5T_1	G_4T_2	
	G_3T_1	G_1T_2	G_3T_2	G_3T_1	G_1T_1	G_3T_2	
	G_7T_1	G_8T_2	G_2T_2	G_7T_1	G_8T_1	G_2T_2	
	G_4T_1	G_6T_2	$G_{10}T_2$	G_4T_1	G_6T_1	$G_{10}T_2$	

1 mt 2 mt 1 mt 2 mt 1 mt 2 mt

Plot Size : 3×4 m^2
Spacing : 20×10 cm
Genotypes : Ten

Design : Factorial RBD
Replications : Three
Treatments : Two

Genotypes:

G_1 : PPR-1012 G_2 : PPR-2885 G_3 : PPR-2773 G_4 : BR-36 G_5 : PPR-1044
G_6 : PPR-1040 G_7 : PR-10-30 G_8 : Sri chaitanya G_9 : Vakula G_{10} : Hima

Treatments:

T_1 : Irrigated (Control); No. of Irrigations: 3
T_2 : Rainfed (No irrigation provided except life saving irrigation at sowing)

Fig. 3.2. Layout plan of the experimental field

Plate 1. Overall view of the experimental field

3.5.2 Fertilizers

Recommended dose of 90 kg N, 40 kg P_2O_5 and 40 kg K ha^{-1} were applied through urea, single super phosphate and muriate of potash respectively to all the plots at the time of sowing. Nitrogen and phosphorus were applied in the form of urea (46% N) and Di Ammonium phosphate (46% P and 18% N) respectively.

3.5.3 Seeds and Sowing

The seed material, obtained from Agricultural Research Station, Perumallapalli. Direct Sowing of seeds were done in the field on 29-08-2015 with a spacing of 20 × 10 cm.

3.5.4 Weeding

Manual weeding was done at 45 days after sowing. Irrigation has given to irrigated plot for 3 times.

3.5.5 Plant Protection

Need based plant protection measures were taken. There was incidence of blast disease and sucking pest during the crop growth period and controlled with recommended pesticide and fungicides.

3.5.6 Sampling Procedure

Destructive and non destructive Sampling was done at 15 days interval. For destructive sampling five plants including root from each treatment or each plot were dug out without roots damage. The plants were thoroughly washed to free dirt and surface dried with blotting paper. Then the plants were dried in hot air oven at 100°C for 15 minutes and then at 80°C for 48 hours until they attained constant weights.

3.6 DATA RECORDED

3.6.1 Growth Parameters

3.6.1.1 Plant height (cm)

Five continuous or random plants in a single row per each plot were selected and tagged. Plant height (cm) was recorded invasively from these plants at 15 days interval till harvest.

3.6.1.2 Leaf area (cm^2 $plant^{-1}$)

After separation of leaves from the plant, leaf area was estimated using leaf area meter (Li-COR model- LI 3000) at 15 days interval and expressed as cm^2 $plant^{-1}$.

3.6.1.3 Total dry matter (g $plant^{-1}$)

The dry weights of oven dried plants (five) were recorded at 15 days interval and expressed as g $plant^{-1}$.

3.6.2 Physiological Attributes

3.6.2.1 Leaf area index

The leaf area index was calculated by dividing the total leaf area with the corresponding ground area as suggested by Watson (1952).

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.6.2.2 Leaf area duration (cm^2 day^{-1})

$$LAD = \frac{(LAI_1 + LAI_2)(T_2 - T_1)}{2}$$

where,

LAI_1 = Leaf area index at time interval T_1 and

LAI_2 = Leaf area index at time interval T_2.

3.6.3 Drought Tolerance traits

3.6.3.1 Water use efficiency traits

3.6.3.1.1 Specific leaf area (SLA) ($cm^2\ g^{-1}$)

SLA is expressed as the ratio between leaf area to leaf dry weight.

$$SLA = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.6.3.1.2 SPAD Chlorophyll Meter Reading (SCMR)

The SPAD meter (Soil Plant Analytical Development) is a simple hand held and portable instrument which provides information on the relative amount of leaf chlorophyll. SCMR values were recorded using the SPAD-502 (Minolta company, NJ, USA (SPAD-502) meter from fully expanded third leaf from top. Mean of five values from five hills was obtained.

3.6.4 Other drought tolerant traits

3.6.4.1 Chlorophyll stability index (CSI)

The chlorophyll stability index (CSI) is an indication of the stress tolerance capacity of plants. A high CSI value means that the stress did not have much effect on chlorophyll content of plants. A higher CSI helps plants to withstand stress through better availability of chlorophyll. This leads to increased photosynthetic rate, more dry matter production and higher productivity.

Chlorophyll stability index CSI (%) was measured using third leaf from top of respective ragi genotypes. Place 0.1 gram amount of fresh leaf sample collected from the selected ragi genotypes in a 100 ml flask and heat it in a water bath for 60 min at 65°C. Add 10 ml of DMSO to treated and untreated samples. Respective checks samples are also maintained without imposing heat treatment. Keep both treated and untreated conical flasks for overnight

and concentration of Chl a, Chl b and total chlorophyll is quantified by reading the optical density at 663nm and 645nm.

$$\text{Total Chl mg/g} = 20.2\ (D645) + 8.02\ (D663) \times V/1000 \times W$$

The CSI of the leaf sample was calculated using the following formula

$$\text{CSI \%} = \frac{\text{Total chlorophyll of the treated sample}}{\text{Total chlorophyll of the untreated sample}} \times 100$$

3.6.4.2 Relative water content (RWC) (%)

RWC is a reliable drought avoidance parameter adopted by plants. Relative water content (RWC) of leaf discs is quantified according to Barrs and Weatherley (1962). Fresh weight of five leaf discs, in triplicates, is recorded from control and stress samples and the leaf discs are floated in water for 6 hours and allowed to gain turgidity. Turgid weights are recorded and dried in hot air oven at 80°C to a constant weight to record dry weight. RWC is estimated and expressed in per cent using the following formula.

$$\text{RWC (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

3.6.4.3 Root length (cm)

Root length was measured using standard scale from ground level the tip of the root after carefully uprooting from ground.

3.6.4.4 Leaf proline content (µg g^{-1})

Proline is a basic amino acid found in higher percentage in basic proteins. Free proline is said to play a role in plants under stress conditions. Though the molecular mechanism has not yet been established for the increased level of proline, one of the hypotheses refers to breakdown of proteins into amino acids and conversion to proline for storage. Many workers have reported several fold increase in proline content under physiological and

pathological stress conditions. Hence, the analysis of proline in plants has become routine in pathology and physiology divisions of agricultural sciences. Proline accumulation was determined as described by Bates *et al*. (1973).

3.6.5 Yield and Yield Components of Finger Millet

3.6.5.1 Number of tillers per plant

The total number of tillers per plant from five hills were counted and averaged to get the number of productive tillers per hill.

3.6.5.2 Finger number per plant

Number of finger per plant was counted for five randomly selected plants and averaged.

3.6.5.3 Test weight 1000-grain weight (g)

Grain samples were drawn from net plot produce for recording 1000-grain weight. Using seed counter, only 1000-grains were sorted out (NUMIGRAL, Type-GTFP No. series – 1367) and weight of these grains were recorded as 1000- grain weight and expressed in g.

3.6.5.4 Grain yield (kg ha^{-1})

The net plot was marked, harvested separately and total dried biomass yield from each net plot was recorded. After threshing, grains were separated, cleaned and weighed. Later the grain yield per net plot was computed to hectare basis and expressed in Kg ha^{-1}.

3.6.5.5 Straw yield (Kg ha^{-1})

Straw yield per net plot was worked out by subtracting respective total grain weight from the total biomass. Later the straw yields per net plot was computed to hectare basis and expressed in kg ha^{-1}.

3.6.5.6 Harvest index (%)

Harvest Index (HI) was expressed as the ratio of seed yield to biological yield and was calculated as given below.

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7 QUALITY PARAMETERS

3.7.1 Calcium

Calcium content of harvested ragi grain was estimated by EDTA titration method stated by Cheng and Bray (1951).

3.7.2 Iron

Iron (Fe) content of harvested ragi grain was determined by using Atomic Absorption Spectrophotometer (AAS) as stated by Lindsay and Novell (1978).

3.7.3 Protein Content (%)

The protein content of the harvested ragi grains was estimated by Infratec™ 1241 Grain analyzer and expressed as percentage.

3.7.4 Fiber Content (%)

Dietary fiber in finger millet samples was analyzed using an Ankom^{220} fiber analyzer (ANKOM Technology, fairport, NY). The contents of crude fiber(CF), acid –detergent fiber (ADF) and neutral-detergent fiber (NDF) were sequentially determined in the ankom fiber analyzer using ankom filter bags F57 (Van Soest *et al.*, 1991; Goering and Van Soest, 1970).

3.8 STATISTICAL ANALYSIS

The experimental data were analyzed statistically by following standard procedure outlined by Panse and Sukhatme (1985). Significance was tested by comparing “F” value at 5 per cent level of probability. The percentage values were transferred wherever necessary and correlation studies were undertaken for different parameters of growth analysis, yield attributes and biochemical parameters according to the method proposed by Fisher and Yates (1963).

Chapter ~ IV

Results & Discussion

Chapter – IV

RESULTS AND DISCUSSION

In this chapter the results and their interpretation on morphological, growth and physiological characters, yield and yield attributes, water use efficiency traits and thermo tolerant traits of ragi genotypes as influenced by rainfed conditions are presented. The data given in tables accordingly and depicted in graphs wherever necessary.

4.1 GROWTH PARAMETERS

4.1.1 Plant Height (cm)

The plant height (cm) of ten ragi genotypes as influenced by rainfed and irrigated conditions are presented in Table 4.1 and Fig. 4.1.

Plant height is a basic growth process and water plays critical role in its regulation. Plant height showed sigmoid growth curve trend and the increase was exponential from 30 DAS to 60 DAS, there after it has increased with decreasing trend. Significant differences between main treatments (irrigated, rainfed) and sub treatments (genotypes) and their interaction were observed at 75 DAS and 90 DAS only. Similar differences in plant height among ragi genotypes were reported by Venkatesh *et al.* (2014).

Audbert (2000) also observed reductions in height (Laude, 1971) leaf area and biomass productions, tiller abortion, changes in rooting pattern and delay development.

Among the rainfed and irrigated treatments, moisture stress (rainfed) significantly reduced plant height by 16.2 per cent at 75 DAS and 17.93 per cent at 90 DAS. Similarly, the test genotypes showed significant differences

Table 4.1. Evaluation of ragi genotypes for plant height (cm) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	19.38	17.38	18.38	31.93	30.06	31.00	57.25	57.14	57.20	74.60	72.10	73.35	90.05	79.69	84.87	93.35	80.35	86.85
PPR-2885	13.24	12.37	12.81	27.98	24.76	26.37	56.10	55.42	55.76	72.88	71.00	71.94	82.53	74.25	78.39	84.17	75.60	79.89
PPR-2773	19.05	18.59	18.82	32.11	30.33	31.22	57.11	56.96	57.04	73.66	70.57	72.12	87.01	74.23	80.62	92.19	80.95	86.57
BR-36	22.39	20.46	21.43	34.86	32.81	33.84	57.33	56.45	56.89	76.55	75.45	76.00	91.03	80.04	85.54	96.63	88.79	92.71
PPR-1044	15.98	20.05	18.01	28.16	25.84	27.00	52.48	51.55	52.02	71.66	66.43	69.05	80.77	69.97	75.37	86.25	71.74	79.00
PPR-1040	14.02	15.87	14.94	28.39	27.01	27.70	53.89	52.34	53.12	66.15	63.42	64.79	84.29	71.08	77.69	81.87	74.69	78.28
PR-10-30	10.52	13.15	11.84	29.56	28.76	29.16	54.23	53.00	53.62	69.57	65.98	67.78	85.41	66.28	75.85	87.85	66.54	77.20
Sri chaitanya	15.67	18.74	17.21	29.10	23.38	26.24	52.97	51.56	52.27	71.66	70.64	71.15	83.51	72.44	77.98	86.25	73.78	80.02
Vakula	14.88	13.78	14.33	27.18	24.76	25.97	51.49	51.69	51.59	68.97	68.69	68.83	79.41	62.34	70.88	79.35	66.54	72.95
Hima	12.69	11.65	12.17	26.12	25.27	25.69	50.65	49.04	49.85	66.15	60.38	63.27	68.12	64.87	66.50	76.47	65.39	70.93
Mean	**15.78**	**16.20**		**29.54**	**27.30**		**54.35**	**53.52**		**71.19**	**68.47**		**83.21**	**71.52**		**86.44**	**74.44**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.2763**	**0.6179**	**0.8739**	**0.679**	**1.5183**	**2.1472**	**0.7085**	**1.5843**	**2.2406**	**1.3384**	**3.1045**	**4.3905**	**1.4331**	**3.2045**	**4.5318**	**1.5472**	**3.4596**	**4.8927**
CD (P=0.05)	**N.S**	**N.S**	**N.S**	**1.9444**	**4.3479**	**N.S**	**N.S**	**4.5371**	**N.S**	**N.S**	**N.S**	**N.S**	**4.1039**	**9.1766**	**N.S**	**4.4307**	**9.9073**	**N.S**

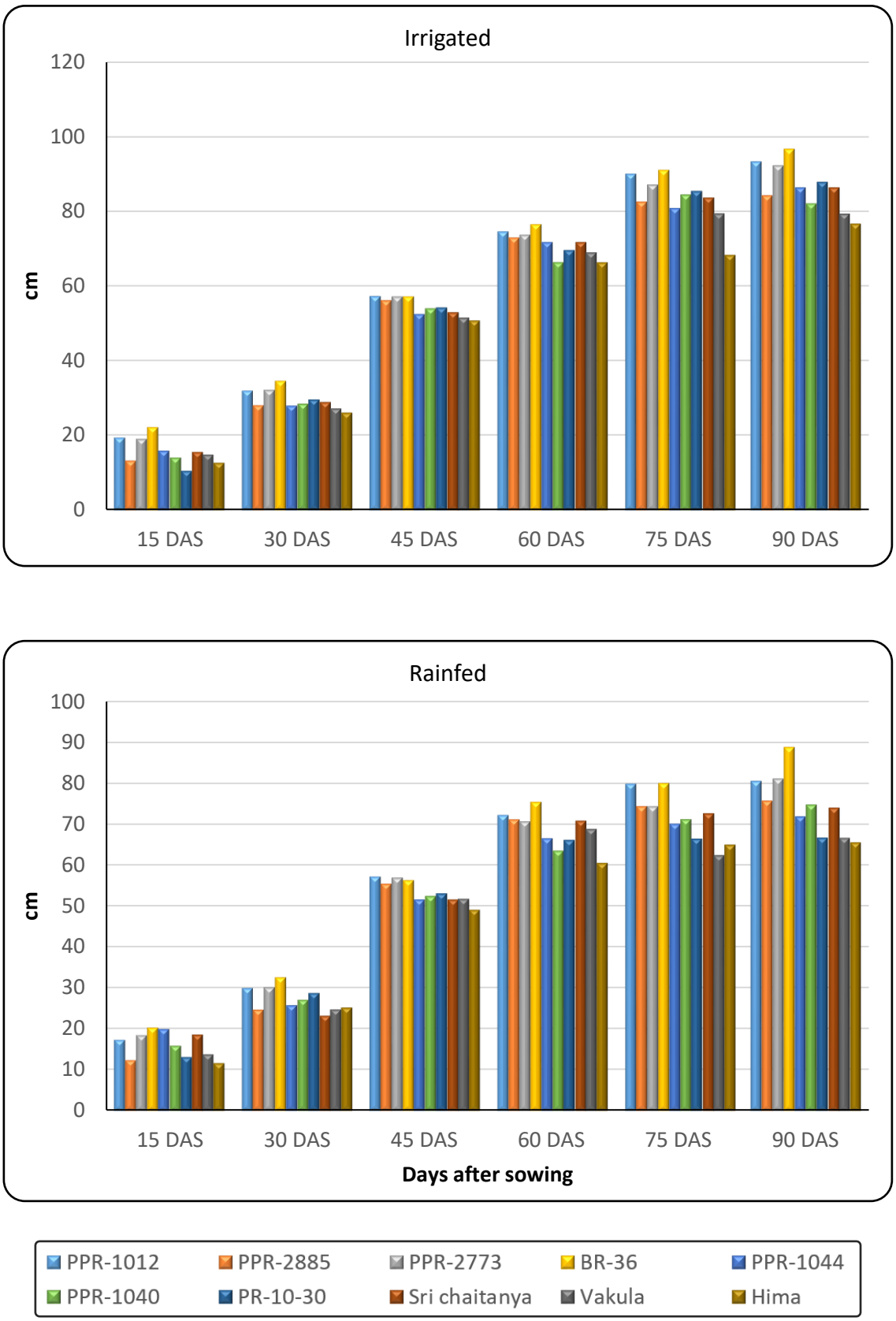


Fig. 4.1. Evaluation of ragi genotypes for plant height (cm) under rainfed conditions

for plant height at 75 DAS and 90 DAS. The genotypes BR-36 recorded highest plant height in both irrigated (96.63 m) and rainfed (88.79 cm) conditions at harvest followed by PPR-1012 and PPR-2773. The genotype Hima was recorded least mean plant height (70.93 cm) as it was drastically affected due to moisture stress.

A similar result of decreasing plant height due to moisture stress was reported in foxtail and pearlmillet (Seghtoleshmi *et al.,* 2008) rice (Suzuki *et al.,* 2015) such decreased plant height in response to drought stress may be due to decrease in relative turgidity and dehydration of protoplasm which is associated with loss of turgor and reduced expansion of cell and cell division (Arnon, 1972).

Growth is the result of daughter-cell production by meristematic cell divisions and subsequent massive expansion of the young cells. Under severe water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells (Nonami, 1998).Drought caused impaired mitosis; cell elongation and expansion resulted in reduced growth and yield traits there by plant height, stem diameter, leaf area decreased noticeably with increasing water stress (Hussain *et al.,* 2006). The reduction in plant height could be attributed to decline in the cell enlargement and more leaf senescence in the plant under water stress (Manivannan *et al.,* 2007).

4.1.2 Leaf Area per Plant (cm^2 $plant^{-1}$)

The leaf area per plant as affected by rainfed and irrigated conditions among ragi genotypes are presented in Table 4.2 and Fig. 4.2.

Leaf area per plant is an important determinant in production and photosynthesis (Watson, 1947). Positive correlation between leaf area and yield (Alluwar and Deotale, 1991) suggests its importance in determining yield.

Table 4.2. Evaluation of ragi genotypes for leaf area (cm^2/plant) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	131.00	154.72	142.86	554.32	523.13	538.73	1060.2	998.12	1029.16	878.62	770.01	824.32	680.00	706.95	693.5	596.10	664.80	630.45
PPR-2885	126.37	129.78	128.08	415.19	433.48	424.34	813.15	842.39	827.77	716.6	581.85	649.23	686.52	442.34	564.4	566.92	421.00	493.96
PPR-2773	131.22	133.89	132.56	496.73	470.05	483.39	1021.6	846.99	934.30	836.45	741.67	789.06	605.79	706.91	656.3	662.11	600.36	631.24
BR-36	133.84	166.26	150.05	608.14	545.45	576.80	1131.0	1000.8	1065.90	930.47	786.54	858.51	846.39	724.12	785.3	702.05	698.21	700.13
PPR-1044	127.00	129.78	128.39	436.70	452.18	444.44	915.29	910.84	913.07	808.03	756.43	782.23	600.57	686.57	643.6	666.20	582.22	624.21
PPR-1040	127.70	125.63	126.67	337.75	356.54	347.15	734.67	722.95	728.81	673.67	550.23	611.95	620.89	449.54	535.2	600.45	416.22	508.34
PR-10-30	129.16	112.98	121.07	449.44	440.14	444.79	810.84	798.00	804.42	708.03	542.15	625.09	677.14	507.27	592.2	643.96	489.16	566.56
Sri chaitanya	126.24	120.76	123.50	450.50	459.56	455.03	852.71	792.71	822.71	715.12	688.98	702.05	690.22	460.53	575.4	672.32	439.74	556.03
Vakula	125.97	98.97	112.47	320.75	331.22	325.99	825.63	863.47	844.55	730.42	636.35	683.39	653.13	506.29	579.7	639.29	470.11	554.70
Hima	125.69	96.44	111.07	390.68	381.12	385.90	692.71	641.99	667.35	562.17	460.7	511.44	533.23	332.16	433.2	451.00	301.53	376.27
Mean	**126.92**	**122.08**		**445.97**	**439.28**		**885.78**	**841.83**		**755.96**	**651.49**		**659.39**	**552.37**		**620.04**	**508.34**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**2.078**	**4.647**	**6.572**	**13.872**	**31.020**	**43.869**	**25.3441**	**56.671**	**80.144**	**19.7818**	**44.2334**	**62.555**	**22.646**	**50.638**	**71.613**	**17.9936**	**40.234**	**56.900**
C.D (P=0.05)	**N.S**	**13.307**	**18.82**	**N.S**	**88.832**	**N.S**	**N.S**	**162.28**	**N.S**	**56.6487**	**126.678**	**N.S**	**64.851**	**145.0113**	**N.S**	**51.5279**	**115.21**	**N.S**

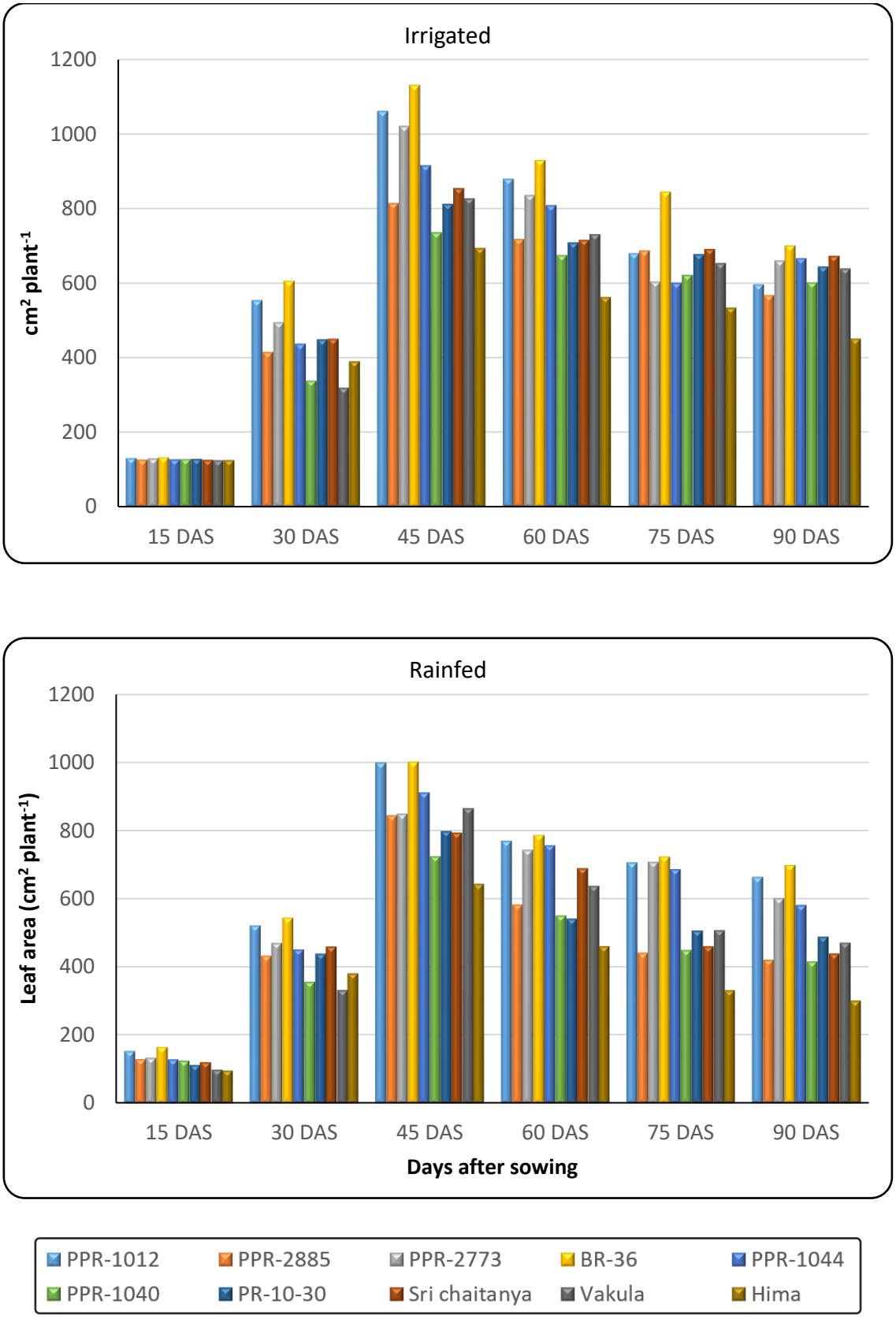


Fig. 4.2. Evaluation of ragi genotypes for leaf area (cm^2 $plant^{-1}$) under rainfed conditions

Drought stress suppresses leaf expansion, tillering and midday photosynthesis(Kramer and Boyer, 1995)and reduces photosynthetic rate and leaf area due to early senescence in rice (Nooden, 1988).The leaf area per plant showed a gradual increase up to 45 DAS and then declined in all the genotypes irrespective of the treatments. Significant differences were observed between treatments, genotypes after 60 DAS and interactions. Similarly significant differences between genotypes under irrigated as well as moisture stress conditions was also reported in ragi (Maqsood and Azam Ali 2007) rice (Sarvestani, 2008) and fingermillet (Venkatesh Babu, 2014).

The data reveals that mean leaf area decreased significantly and the extent of decrease was 13.8 per cent at 60 DAS, 22 per cent at 75 DAS and 18.0 per cent at 90 DAS. Fukai and Cooper (1995) opined that possible causes for drought affected leaf area development as reduced leaf expansion, leaf rolling and early senescence.

Among the genotypes, BR-36, PPR-1012 and PPR-2773 recorded higher leaf area both under irrigated as well as rainfed conditions. PPR-2885, PPR-1040, PPR-1044, PR-10-30 and Vakula recorded moderate leaf area, whereas PPR -1040 and Hima recorded significantly lowest leaf area. Leaf area expansion depends on leaf turgor, temperature, and assimilating supply for growth. Drought-induced reduction in leaf area is ascribed to suppression of leaf expansion through reduction in photosynthesis (Rucker *et al.,* 1995).

4.1.3 Dry matter partitioning (g plant^{-1})

The total dry weight per plant of ragi genotypes under rainfed and irrigated conditions were recorded at 15 days interval and presented in Table 4.3 and Fig. 4.3.

Dry matter accumulation and distribution is an important factor indicating partitioning efficiency of a genotype. In general, soil moisture determines the accumulation of dry matter in different plant parts. The data

indicated that irrespective of the treatments, there was a two-three fold increase in total plant dry weight between 15-75 DAS and thereafter it was decreased relatively as the crop reached maturity. Significant differences were observed between treatments from 60 DAS to 90 DAS and only numerical differences were recorded between genotypes and their interactions. Similar significant differences were reported in pearl millet (Vijayalakshmi *et al*., 2012), ragi (Maqsood and Azam Ali 2007) and rice (Chauhan *et al.*, 1996).

Mean total plant dry matter significantly decreased due to moisture stress from 47 to 67 DAS in rainfed treatment compared to irrigated treatment. The extent of decrease was 27.8 per cent at 60 DAS, 21.2 per cent at 75 DAS and 26.1 per cent at 90 DAS compared to respective irrigated treatments. These results indicated that moisture stress drastically affected total plant dry weight similar to plant height. Such decrease in dry matter accumulation of ragi genotypes due to moistures stress was reported by Maqsood and Azam Ali (2007) and Venkatesh Babu *et al.* (2014). Gifford *et al.* (1979) reported that the reduction in leaf expansion and its photosynthetic rate of rice crop, due to moderate water deficits caused reduction in dry matter production and grain yield.

Among the ragi genotypes tested BR-36 recorded highest total plant dry matter under irrigated (48.92 g plant^{-1}) as well as rainfed (34.22 g plant^{-1}) conditions followed by PPR-2885, PPR-1012 and PPR-2773. It denotes the drought tolerant capability of these genotypes as they maintained higher physiological activity in terms of higher green leaf area, thus sustained higher total plant dry weight. Similar genotypic variability among genotypes under irrigated as well as moisture stress conditions was reported in rice (Renuka Devi *et al*., 2013) and finger millet (Venkateshbabu *et al*., 2014). Dry matter production at flowering would lead to remobilization of photosynthates to reproductive structures and high-biomass during post

Table 4.3. Evaluation of ragi genotypes for total dry matter (g) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	0.58	0.77	0.67	4.09	4.04	4.11	26.45	29.24	27.85	43.36	31.90	37.63	45.46	41.84	43.65	43.43	31.46	37.45
PPR-2885	0.77	0.76	0.76	3.90	3.84	3.92	24.88	23.80	24.34	40.59	31.95	36.27	47.23	40.59	43.91	44.56	35.46	40.01
PPR-2773	0.81	0.72	0.76	4.08	4.05	4.11	25.28	29.12	27.20	38.51	33.17	35.84	42.36	39.94	41.15	41.89	35.66	38.78
BR-36	0.94	0.81	0.88	4.25	4.23	4.29	37.73	32.64	35.19	42.76	36.72	39.74	49.38	41.38	45.38	48.92	37.22	43.07
PPR-1044	0.81	0.81	0.81	3.92	3.90	3.96	24.74	28.32	26.53	45.55	30.23	37.89	44.43	38.06	41.245	41.19	33.24	37.22
PPR-1040	0.72	0.72	0.72	4.06	3.05	3.59	25.93	22.20	24.07	37.23	28.77	33.00	44.15	34.42	39.285	41.00	29.81	35.41
PR-10-30	0.76	0.63	0.70	3.98	3.95	4.00	27.78	30.59	29.19	40.51	31.03	35.77	45.61	37.45	41.53	38.15	28.64	33.40
Sri chaitanya	0.67	0.68	0.67	4.07	4.02	4.11	25.37	25.22	25.30	35.82	26.62	31.22	42.02	32.56	37.29	39.46	29.12	34.29
Vakula	0.76	0.59	0.67	3.80	3.72	3.80	29.81	28.75	29.28	40.55	30.30	35.43	44.80	40.64	42.72	39.51	30.34	34.93
Hima	0.63	0.59	0.61	3.75	3.65	3.74	24.09	23.05	23.57	35.59	28.73	32.16	44.64	37.64	41.14	40.32	32.65	36.49
Mean	**0.75**	**0.71**		**3.99**	**3.85**		**27.207**	**27.293**		**40.05**	**30.94**		**45.01**	**38.45**		**41.84**	**32.36**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.1158**	**0.2590**	**0.3663**	**0.2836**	**0.6342**	**0.8970**	**1.0523**	**2.3531**	**3.3277**	**1.4817**	**3.3132**	**4.6856**	**1.9518**	**4.3644**	**6.1722**	**2.0355**	**4.5514**	**6.4367**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**6.7384**	**N.S**	**4.2431**	**N.S**	**N.S**	**5.5894**	**N.S**	**N.S**	**5.8289**	**N.S**	**N.S**

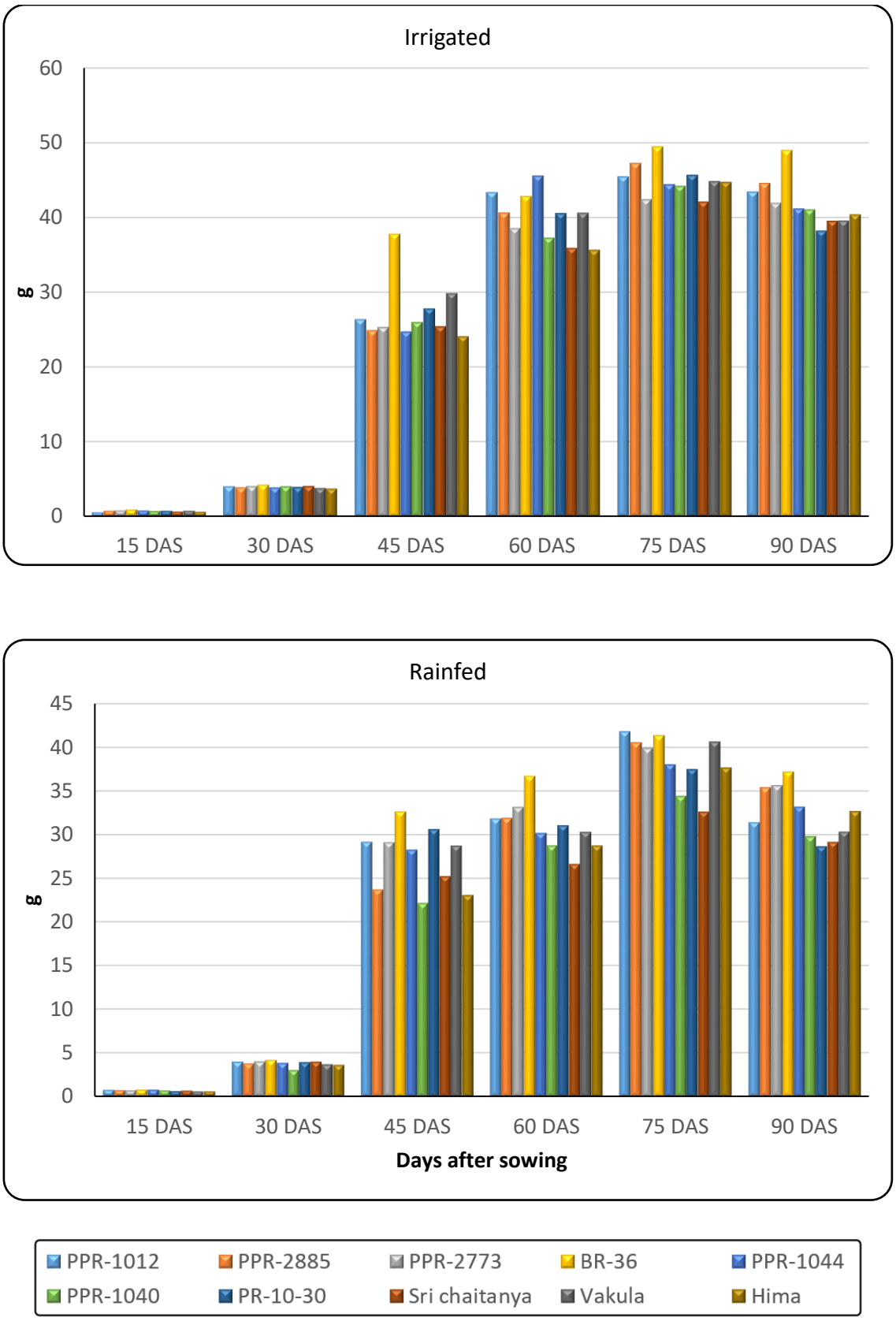


Fig. 4.3. Evaluation of ragi genotypes for total dry matter (g) under rainfed conditions

anthesis directly involved in enhancing there productive structures thus higher grain yield of finger millet crop (Chaudhuri, 1989).

4.1.3.1 Leaf dry weight per plant

The leaf dry weight of ragi genotypes under rainfed and irrigated conditions were recorded at 15 days interval and presented in Table 4.4 and Fig. 4.4.

Retention of green leaves under drought conditions has been used as a selection criterion for drought resistance. The data indicated that irrespective of the treatments, there was a two-three fold increase in total plant dry weight between 15-75 DAS and thereafter it was marginally decreased as the crop reached maturity. Similar to total plant dry weight, leaf dry weight also showed significant differences between treatments from 60 DAS to 90 DAS and only numerical differences were recorded between genotypes and their interactions.

Mean leaf dry weight decreased significantly due to moisture stress from 35-60 DAS in rainfed treatments compared to irrigated treatments. The extent of decrease was 28.4 per cent at 60 DAS, 22.8 per cent at 75 DAS and 27.1 per cent at 90 DAS compared to respective irrigated treatments. These results indicated that moisture stress at grand growth stage affected leaf growth and leaf dry weight. Drought tolerant rice variety is able to retain green leaves longer than two other susceptible cultivars under drought conditions (Mostajeran and Rahimi-Echi, 2009).

Among the genotypes tested BR-36 recorded highest total plant dry matter under irrigated (10.76 g plant^{-1}) as well as rainfed (7.53 g plant^{-1}) conditions followed by PPR-1012, PPR-2885 and PPR – 2773. These results reveal that moisture stress affect leaf growth to prevent transpiration in ragi crop also, however genotypic differences exists in sustaining leaf growth and its dry weight under low soil moisture conditions.

Table 4.4. Evaluation of ragi genotypes for leaves dry weight (g) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	0.52	0.68	0.60	2.73	2.69	2.71	5.82	6.43	6.13	6.5	7.54	7.02	8.28	10.48	9.38	9.55	6.70	8.13
PPR-2885	0.68	0.68	0.68	2.60	2.56	2.58	5.47	5.24	5.36	6.37	6.93	6.65	10.39	8.71	9.55	9.80	6.48	8.14
PPR-2773	0.72	0.64	0.68	2.72	2.70	2.71	5.56	6.41	5.98	6.59	7.47	7.03	7.97	9.70	8.84	9.21	6.96	8.09
BR-36	0.84	0.72	0.78	2.83	2.82	2.83	8.30	7.18	7.74	7.13	7.41	7.27	10.53	8.66	9.60	10.76	7.53	9.14
PPR-1044	0.72	0.72	0.72	2.61	2.60	2.61	5.44	6.23	5.84	6.43	8.02	7.23	7.48	10.54	9.01	9.06	7.09	8.07
PPR-1040	0.64	0.64	0.64	2.71	2.03	2.37	5.70	4.88	5.29	6.11	6.17	6.14	9.71	7.13	8.42	9.02	6.34	7.68
PR-10-30	0.68	0.56	0.62	2.65	2.63	2.64	6.11	6.73	6.42	6.61	6.91	6.76	10.03	8.02	9.03	8.38	6.08	7.23
Sri chaitanya	0.60	0.60	0.60	2.71	2.70	2.71	5.58	5.55	5.57	5.64	7.88	6.76	9.57	6.72	8.14	8.68	6.18	7.43
Vakula	0.68	0.52	0.60	2.53	2.48	2.51	6.56	6.33	6.44	6.45	6.92	6.69	9.86	7.84	8.85	6.49	5.55	6.02
Hima	0.56	0.52	0.54	2.50	2.43	2.47	5.30	5.07	5.19	6.1	5.83	5.97	9.82	7.62	8.72	8.87	6.96	7.92
Mean	**0.66**	**0.63**		**2.659**	**2.565**		**5.957**	**6.005**		**8.806**	**6.393**		**9.36**	**8.54**		**8.983**	**6.587**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.0426**	**0.0954**	**0.1349**	**0.1892**	**0.423**	**0.5982**	**0.387**	**0.8654**	**1.2238**	**0.3089**	**0.6907**	**0.9768**	**0.2388**	**0.5339**	**0.7551**	**0.1972**	**0.441**	**0.6237**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**0.8845**	**N.S**	**N.S**	**N.S**	**1.5289**	**N.S**	**0.5648**	**1.2629**	**N.S**

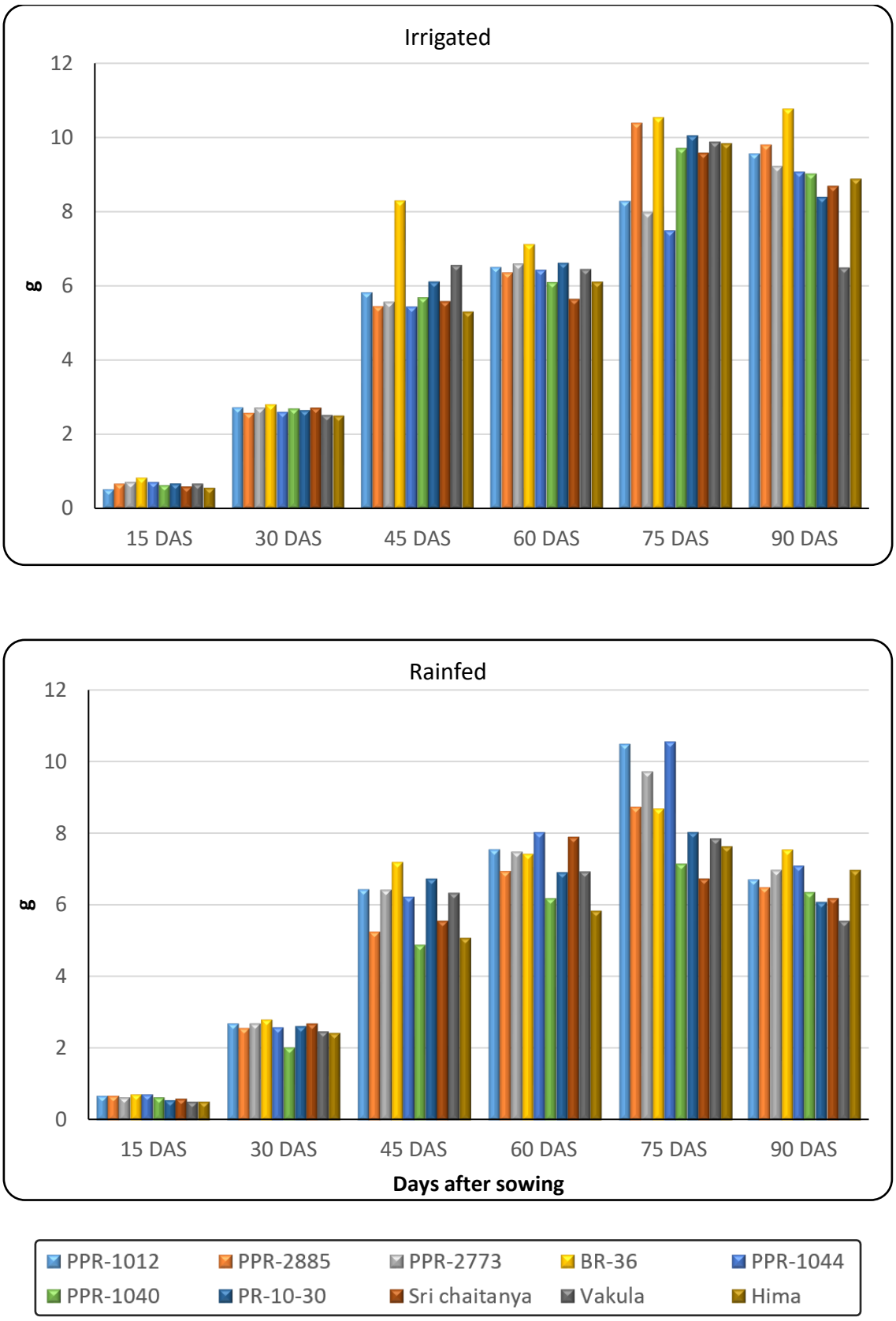


Fig. 4.4. Evaluation of ragi genotypes for leaves dry weight (g) under rainfed conditions

4.1.3.2 Stem dry weight per plant

The leaf dry weight of ragi genotypes under rainfed and irrigated conditions were recorded at 15 days interval and presented in Table 4.5 and Fig. 4.5.

The data on stem dry weight throughout growing season followed similar trend as that of leaf dry weight. Stem dry weight also showed significant differences between treatments from 60 DAS to 90 DAS and only numerical differences were recorded between genotypes and their interactions. Such differences among irrigation and moisture stress treatments were reported by Mostajeran and Rahimi-Echi (2009) in rice crop.

Shoot dry weight was also affected under rainfed condition compared to control treatment. Decrease in shoot dry matter under lower soil moisture might be due to reduction of leaf area and photosynthetic rate. The extent of decrease was 33.1 per cent at 60 DAS, 21.7 per cent at 75 DAS and 23.68 per cent at 90 DAS compared to respective irrigated treatments. Among the ragi genotypes BR-36 maintained higher stem dry weight under rainfed as well as irrigated conditions followed by PPR-1012, PPR-2885 and PPR – 2773 throughout growing season.

Mohammedkhani and Heidari (2008) reported that significant reduction in shoot dry weight of rice varieties at drought conditions might be due to low osmotic potential as well as a decrease in wall extensibility and cellular expansion.

Table 4.5. Evaluation of ragi genotypes for stem dry weight (g) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	0.05	0.06	0.05	0.99	0.98	0.99	18.25	20.18	19.21	32.96	20.10	26.5	32.89	25.98	29.44	29.97	21.02	25.50
PPR-2885	0.06	0.06	0.06	0.95	0.93	0.94	17.17	16.42	16.79	30.57	21.41	26.0	32.59	27.32	29.95	30.75	21.91	26.33
PPR-2773	0.06	0.06	0.06	0.99	0.98	0.99	17.45	20.09	18.77	28.45	21.80	25.1	30.42	24.98	27.70	28.91	24.85	26.88
BR-36	0.08	0.06	0.07	1.03	1.03	1.03	26.03	22.52	24.28	31.78	25.09	28.4	34.41	27.17	3079	33.76	26.61	30.19
PPR-1044	0.06	0.07	0.07	0.95	0.95	0.95	17.07	19.54	18.31	35.02	18.58	26.8	33.04	23.46	28.25	28.41	22.25	25.33
PPR-1040	0.06	0.06	0.06	0.98	0.74	0.86	17.96	15.32	16.64	27.77	19.10	23.4	30.47	22.37	26.42	28.29	19.88	24.09
PR-10-30	0.06	0.05	0.06	0.96	0.96	0.96	19.08	21.11	20.09	30.25	20.42	25.3	31.48	25.15	28.31	26.34	19.07	22.71
Sri chaitanya	0.05	0.06	0.05	0.99	0.96	0.97	17.60	17.40	17.50	26.96	15.43	21.2	28.67	21.09	24.88	27.23	19.41	23.32
Vakula	0.06	0.05	0.05	0.92	0.90	0.91	20.57	19.83	20.20	30.45	19.74	25.1	30.91	27.59	29.25	30.36	21.82	26.09
Hima	0.05	0.05	0.05	0.91	0.89	0.90	16.62	15.91	16.26	26.29	19.40	22.8	30.80	24.81	27.81	27.82	21.84	24.83
Mean	**0.06**	**0.06**		**0.97**	**0.93**		**18.78**	**18.83**		**30.1**	**20.1**		**31.57**	**24.99**		**29.18**	**21.86**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.0043**	**0.0096**	**0.0135**	**0.0599**	**0.1399**	**0.1894**	**1.0894**	**2.4360**	**3.4450**	**1.2289**	**2.748**	**3.8863**	**1.3047**	**2.9173**	**4.1257**	**0.9958**	**2.2266**	**3.1489**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**3.5193**	**N.S**	**N.S**	**3.7362**	**N.S**	**N.S**	**2.8516**	**N.S**	**N.S**

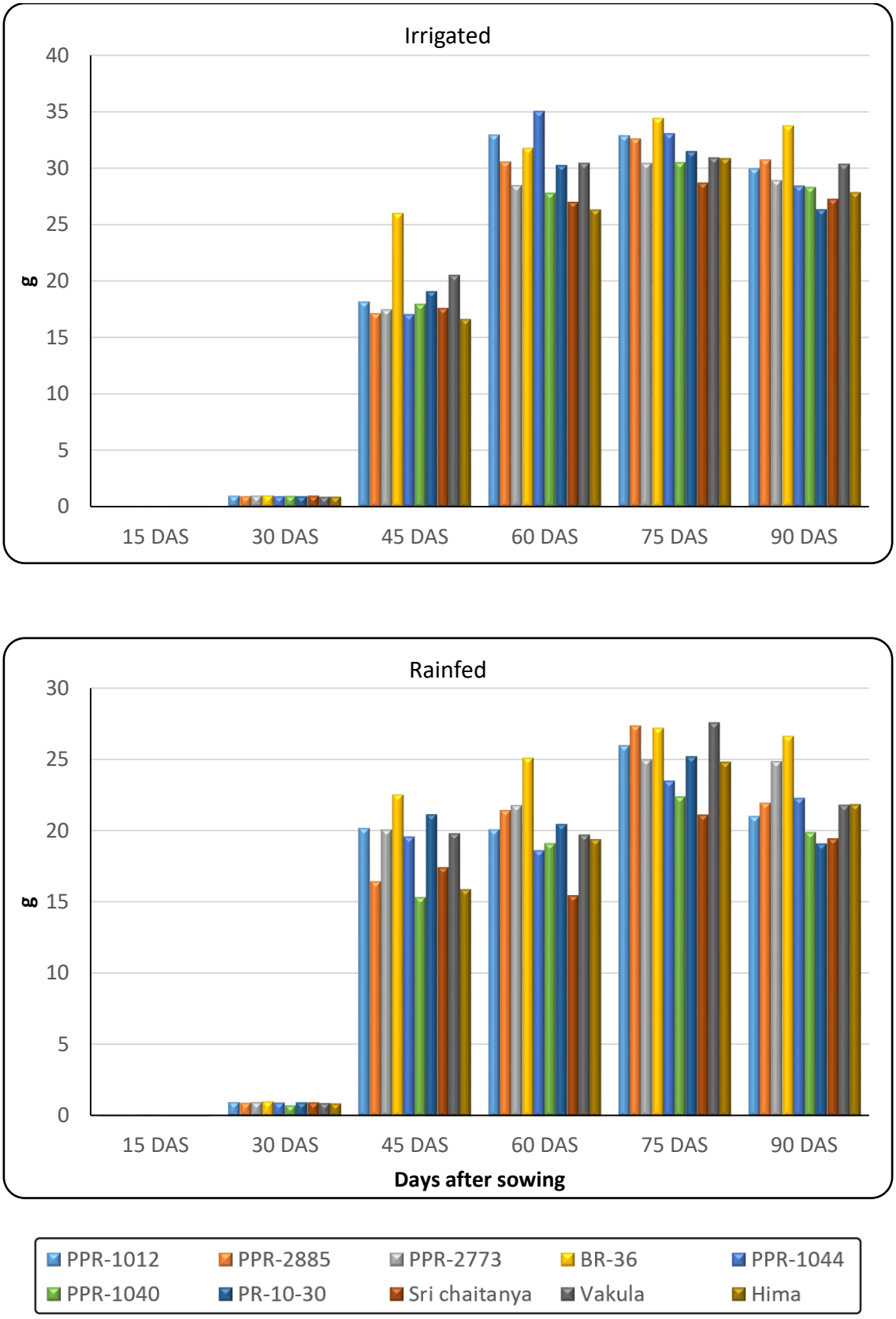


Fig. 4.5. Evaluation of ragi genotypes for stem dry weight (g) under rainfed conditions

4.1.3.3 Root dry weight per plant

The root dry weight of ragi genotypes under rainfed and irrigated conditions were recorded at 15 days interval and presented in Table 4.6 and Fig. 4.6.

Root dry weight of a plant indicates its capability in drawing water and nutrients from soil. High rooting abilities is desirable drought tolerant genotype. Root dry weight showed no significant differences between treatments, genotypes and their interaction before 75 DAS. However at harvest genotypic variability for root dry weight is significant.

Root dry weight of ragi genotypes was less affected in rainfed treatment compared to control treatments. The increase observed in root weight under moisture stress indicate greater density of root and or greater depths of root penetration, both of these are important morphological adaptations to moisture deficit and results in greater extraction of soil water (Hoogcnboom*et al.* 1987).

BR-36 maintained higher root dry weight under rainfed as well as irrigated conditions followed by PPR-1012, PPR-2885 and PPR-2773. These results reveal that the same genotypes recorded higher leaf and stem dry weights, which denotes that these genotypes maintained higher rooting abilities under rainfed situation.

Table 4.6. Evaluation of ragi genotypes for roots dry weights (g) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	0.017	0.023	0.020	0.371	0.368	0.37	2.381	2.632	2.507	3.902	4.256	4.08	4.287	5.377	4.83	3.909	3.741	3.83
PPR-2885	0.023	0.022	0.022	0.354	0.35	0.352	2.239	2.142	2.19	3.653	3.606	3.63	4.25	4.563	4.41	4.01	7.07	5.54
PPR-2773	0.024	0.021	0.023	0.37	0.369	0.37	2.275	2.621	2.448	3.465	3..897	3.47	3.967	5.257	4.61	3.77	3.849	3.81
BR-36	0.028	0.024	0.026	0.386	0.385	0.385	3.396	2.938	3.167	3.848	4.218	4.03	4.443	5.547	5.00	4.403	3.08	3.74
PPR-1044	0.024	0.025	0.024	0.356	0.355	0.356	2.227	2.549	2.388	4.1	3.631	3.87	3.91	4.06	3.99	3.715	3.902	3.81
PPR-1040	0.021	0.021	0.021	0.369	0.277	0.323	2.275	1.998	2.137	3.351	3.499	3.43	3.973	4.92	4.45	3.69	3.593	3.64
PR-10-30	0.022	0.018	0.020	0.361	0.359	0.36	2.59	2.753	2.672	3.646	3.703	3.67	4.103	4.28	4.19	3.43	3.488	3.46
Sri chaitanya	0.019	0.020	0.020	0.369	0.36	0.365	2.194	2.27	2.232	3.224	3.306	3.27	3.78	4.75	4.27	3.551	3.531	3.54
Vakula	0.022	0.018	0.020	0.345	0.338	0.342	2.683	2.588	2.636	3.65	3.637	3.64	4.03	5.207	4.62	2.655	2.972	2.81
Hima	0.018	0.018	0.018	0.341	0.332	0.336	2.168	2.075	2.121	3.203	3.496	3.35	4.017	5.213	4.62	3.629	3.849	3.74
Mean	**0.0227**	**0.0214**		**0.362**	**0.394**		**2.442**	**2.456**		**3.604**			**4.076**	**4.917**		**3.676**	**3.908**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.001**	**0.0022**	**0.0031**	**0.0339**	**0.0758**	**0.1072**	**0.1736**	**0.3883**	**0.5491**	**0.1715**	**0.3834**	**0.5423**	**0.2319**	**0.7332**	**0.2565**	**0.2133**	**0.4770**	**0.6746**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**0.6640**	**N.S**	**N.S**	**N.S**	**1.3660**	**N.S**

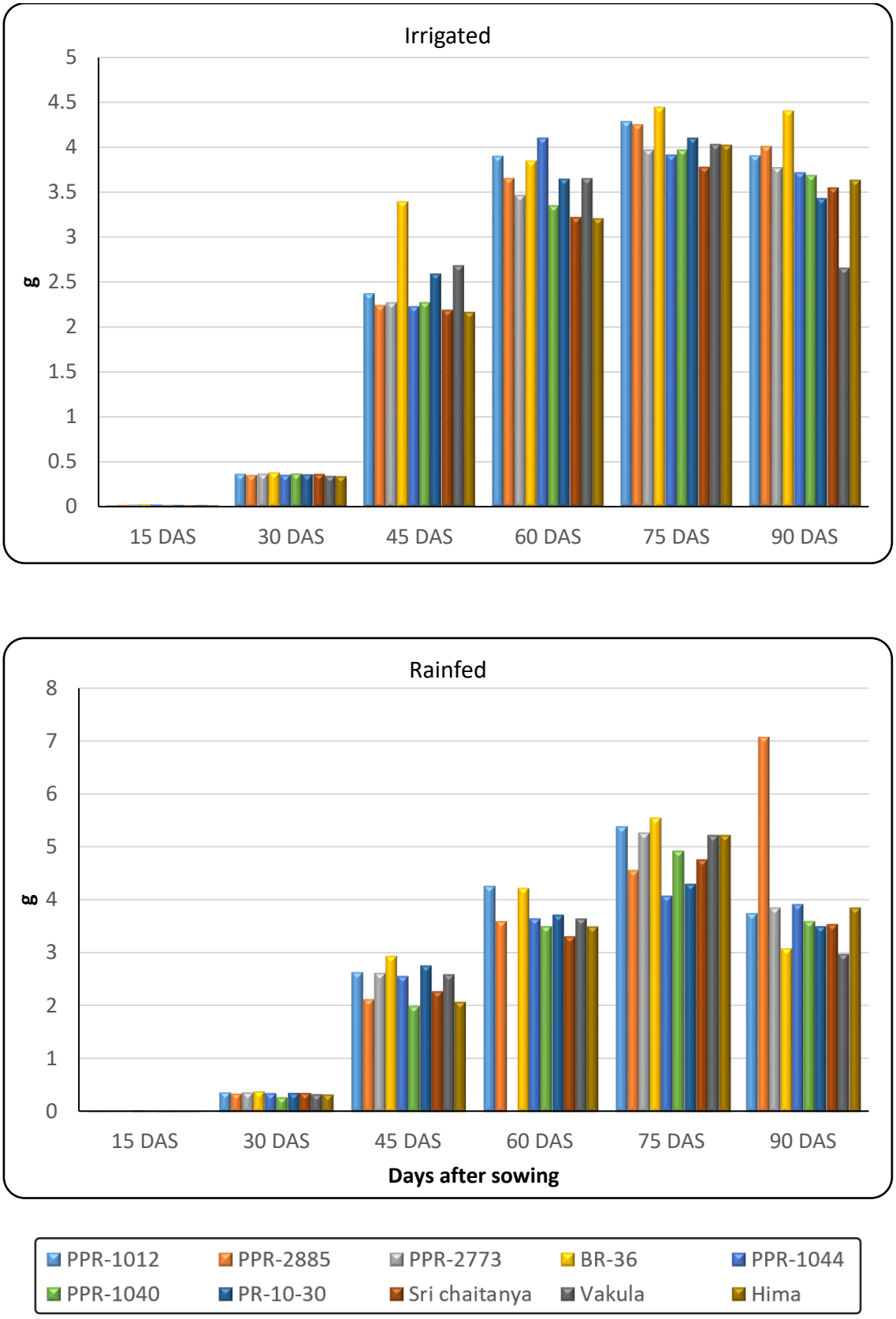


Fig. 4.6. Evaluation of ragi genotypes for roots dry weights (g) under rainfed conditions

4.2 PHYSIOLOGICAL ATTRIBUTES

4.2.1 Leaf Area Index

The leaf area index of ragi genotypes under rainfed and irrigated conditions were recorded at 15 days interval and presented in Table 4.7 and Fig. 4.7.

Leaf Area Index (LAI) is an important plant factor in determining the dry matter accumulation and hence the crop yield. The LAI was directly related to grain yield in wheat and maintenance of high LAI at antithesis would be desirable for obtaining higher yield in the stressed plants (Aggarwal and Sinha, 1987, Bakheit *et al.*, 1989).

Significant differences were not observed between genotypes, moisture stress treatments and their interactions up to 60 DAS. However significant differences were observed at 75 DAS between treatments and at 90 DAS between treatments and genotypes. Maqsood and Azam Ali (2007) reported significant differences among genotypes under irrigated as well as moisture stress in finger millet.

Similar to leaf area, leaf area index also increased upto 45 DAS and declined thereafter. Dry spell from 47-67 DAS significantly decreased mean leaf area index of rainfed treatment by 16.10 per cent at 75 DAS and 18.06 per cent at 90 DAS compared to irrigated control. Such decrease in LAI of ragi genotypes due to moistures stress was reported by Maqsood and Azam Ali (2007) and Venkatesh Babu *et al.* (2014).

Among the ragi genotypes BR-36 maintained higher LAI under rainfed as well as irrigated conditions followed by PPR-1012 and PPR-2773 throughout growing season. These results further establish the superiority of BR-36, PPR-1012 and PPR-2773 in maintaining higher physiological efficiency both under irrigated and moisture stress conditions.

Table 4.7. Evaluation of ragi genotypes for leaf area index under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	0.66	0.77	0.71	2.77	2.62	2.69	5.30	4.99	5.15	4.39	3.85	4.12	3.40	3.53	3.47	2.98	3.32	3.15
PPR-2885	0.63	0.65	0.64	2.08	2.17	2.12	4.07	4.21	4.14	3.58	2.91	3.25	3.43	2.21	2.82	2.83	2.11	2.47
PPR-2773	0.66	0.67	0.66	2.48	2.35	2.42	5.11	4.23	4.67	4.18	3.71	3.95	3.03	3.53	3.28	3.31	3.00	3.16
BR-36	0.67	0.83	0.75	3.04	2.73	2.88	5.66	5.00	5.33	4.65	3.93	4.29	4.23	3.62	3.93	3.51	3.49	3.50
PPR-1044	0.64	0.65	0.64	2.18	2.26	2.22	4.58	4.55	4.57	4.04	3.78	3.91	3.00	3.43	3.22	3.33	2.91	3.12
PPR-1040	0.64	0.63	0.63	1.69	1.78	1.74	3.67	3.61	3.64	3.37	2.75	3.06	3.10	2.25	2.68	3.00	2.08	2.54
PR-10-30	0.65	0.56	0.61	2.25	2.20	2.22	4.05	3.99	4.02	3.54	2.71	3.13	3.39	2.54	2.96	3.22	2.45	2.83
Sri chaitanya	0.63	0.60	0.62	2.25	2.30	2.28	4.26	3.96	4.11	3.58	3.44	3.51	3.45	2.30	2.88	3.36	2.20	2.78
Vakula	0.63	0.49	0.56	1.60	1.66	1.63	4.13	4.32	4.22	3.65	3.18	3.42	3.27	2.53	2.90	3.20	2.35	2.77
Hima	0.63	0.48	0.56	1.95	1.91	1.93	3.46	3.21	3.34	2.81	2.30	2.56	2.67	1.66	2.16	2.26	1.51	1.88
Mean	**0.64**	**0.63**		**2.23**	**2.20**		**4.43**	**4.21**		**3.78**	**3.26**		**3.29**	**2.76**		**3.10**	**2.54**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.0759**	**0.1698**	**0.2402**	**0.2091**	**0.4676**	**0.6613**	**0.2436**	**0.5447**	**0.7703**	**0.2375**	**0.5310**	**0.7510**	**0.1859**	**0.4158**	**0.5880**	**0.1341**	**0.2999**	**0.4241**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**0.5324**	**N.S**	**N.S**	**0.3841**	**0.8588**	**N.S**

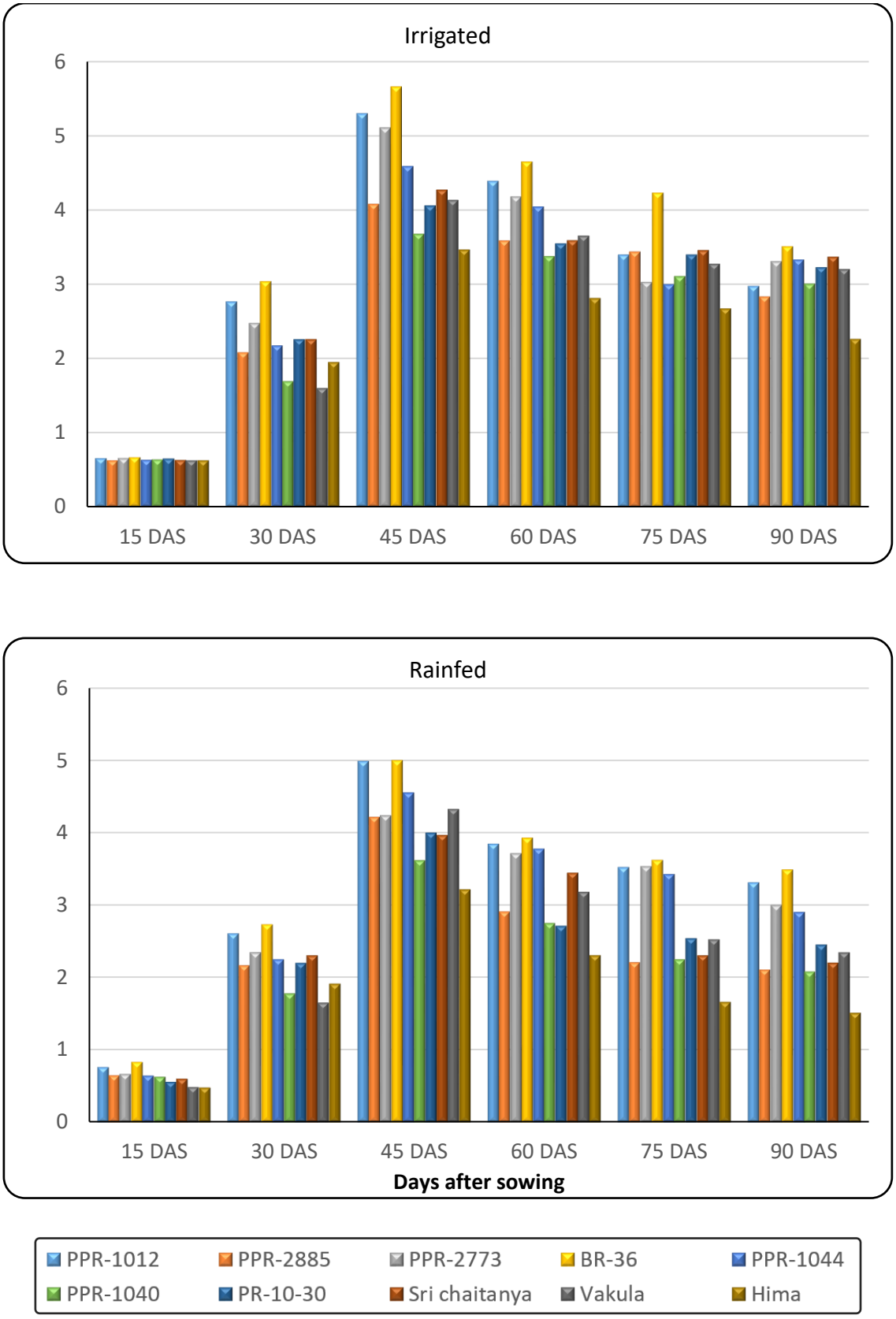


Fig. 4.7. Evaluation of ragi genotypes for leaf area index under rainfed conditions

4.2.2 Leaf Area Duration

Leaf area duration (LAD) of ragi genotypes under rainfed and irrigated conditions were recorded at 15 days interval and presented in Table 4.8 and Fig. 4.8.

Leaf area duration indicates stay- greeness of a genotype in crop duration. It is an useful growth parameter indicating the efficiency of photosynthetic system, with a high degree of association with dry matter accumulation (Chetti and Sirohi, 1995). Higher LAD especially during grain filling stage has profound influence on yield and its attributes.

Significant differences were observed between genotypes throughout the duration, however such differences between treatments were observed only 45-60 DAS onwards. But their interactions effects were not significant. Moisture stress at 47-67 DAS significantly decreased mean LAD to the extent of 9.04 per cent at 45-60 DAS, 14.9 per cent at 60-75 DAS and 17.11 per cent at 75-90 DAS. Similar results of reduction of LAD under moisture stress was also reported in ragi by Krishnasastry *et al*. (1981) and Venkatesh Babu *et al.* (2014), in rice by Chauhan *et al.* (1996) and Renuka Devi *et al.* (2013).

Similar to LAI, BR-36 PPR-1012 and PPR-2773 recorded highest LAD, than other genotypes. Hima recorded lowest LAD. PPR-2885, PPR-773, PR-10-30, PPR-1040, PPR-1044, Sri Chaitanya and Vakula recorded moderate leaf area duration. The three genotypes BR-36 PPR-1012 and PPR-2773 also possess the higher leafyness specially at grain filling stage compared to other genotypes and thus proved efficient in current photosynthesis and higher grain filling characters.

Higher LAD may be one of reason for higher photosynthetic rate and dry matter production in genotypes BR-36 PPR-1012 and PPR-2773. Significant positive correlation between LAD and yield was reported by Nighwan and Chandra (1980), Chandrasekhar *et al*. (2001) and Katsura *et al.* (2007).

Table 4.8. Evaluation of ragi genotypes for leaf area duration (days) under rainfed conditions

	15-30 DAS			30-45 DAS			45-60 DAS			60-75 DAS			75-90 DAS		
Genotype	**Irrigated**	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**	**Irrigated**	**Rainfed**	**Mean**
PPR-1012	25.70	25.42	25.56	60.54	57.05	58.80	72.71	66.30	69.51	58.45	55.39	56.92	47.85	51.44	49.65
PPR-2885	20.31	21.12	20.72	46.06	47.85	46.95	57.37	53.41	55.39	52.62	38.41	45.52	47.00	32.38	39.69
PPR-2773	23.55	22.65	23.10	56.94	49.39	53.16	69.68	59.57	64.63	54.08	54.32	54.20	47.55	49.02	48.29
BR-36	27.82	26.69	27.26	65.22	57.98	61.60	77.31	67.03	72.17	66.63	56.65	61.64	58.07	53.34	55.71
PPR-1044	21.14	21.82	21.48	50.70	51.11	50.91	64.62	62.52	63.57	52.82	54.11	53.47	47.50	47.58	47.54
PPR-1040	17.45	18.08	17.77	40.22	40.48	40.35	52.81	47.74	50.28	48.55	37.49	43.02	45.80	32.47	39.14
PR-10-30	21.70	20.74	21.22	47.26	46.43	46.85	56.96	50.26	53.61	51.94	39.35	45.65	49.54	37.37	43.46
Sri chaitanya	21.63	21.76	21.69	48.87	46.96	47.92	58.79	55.56	57.18	52.70	43.11	47.91	51.10	33.76	42.43
Vakula	16.75	16.13	16.44	42.99	44.80	43.90	58.35	56.24	57.30	51.88	42.85	47.37	48.47	36.62	42.55
Hima	19.36	17.91	18.64	40.63	38.37	39.50	47.06	41.35	44.20	41.08	29.73	35.41	36.91	23.76	30.34
Mean	**21.54**	**21.23**		**49.94**	**48.04**		**61.57**	**56.00**		**53.08**	**45.14**		**47.98**	**39.77**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.9220**	**2.0616**	**2.9156**	**2.1791**	**4.8726**	**6.8909**	**1.6891**	**3.7768**	**5.3413**	**1.8274**	**4.0861**	**5.7786**	**1.5022**	**3.3590**	**4.7503**
CD(P=0.005)	**N.S**	**5.9039**	**N.S**	**N.S**	**13.953**	**N.S**	**4.8369**	**10.815**	**N.S**	**5.2330**	**11.7013**	**N.S**	**4.3018**	**9.6190**	**N.S**

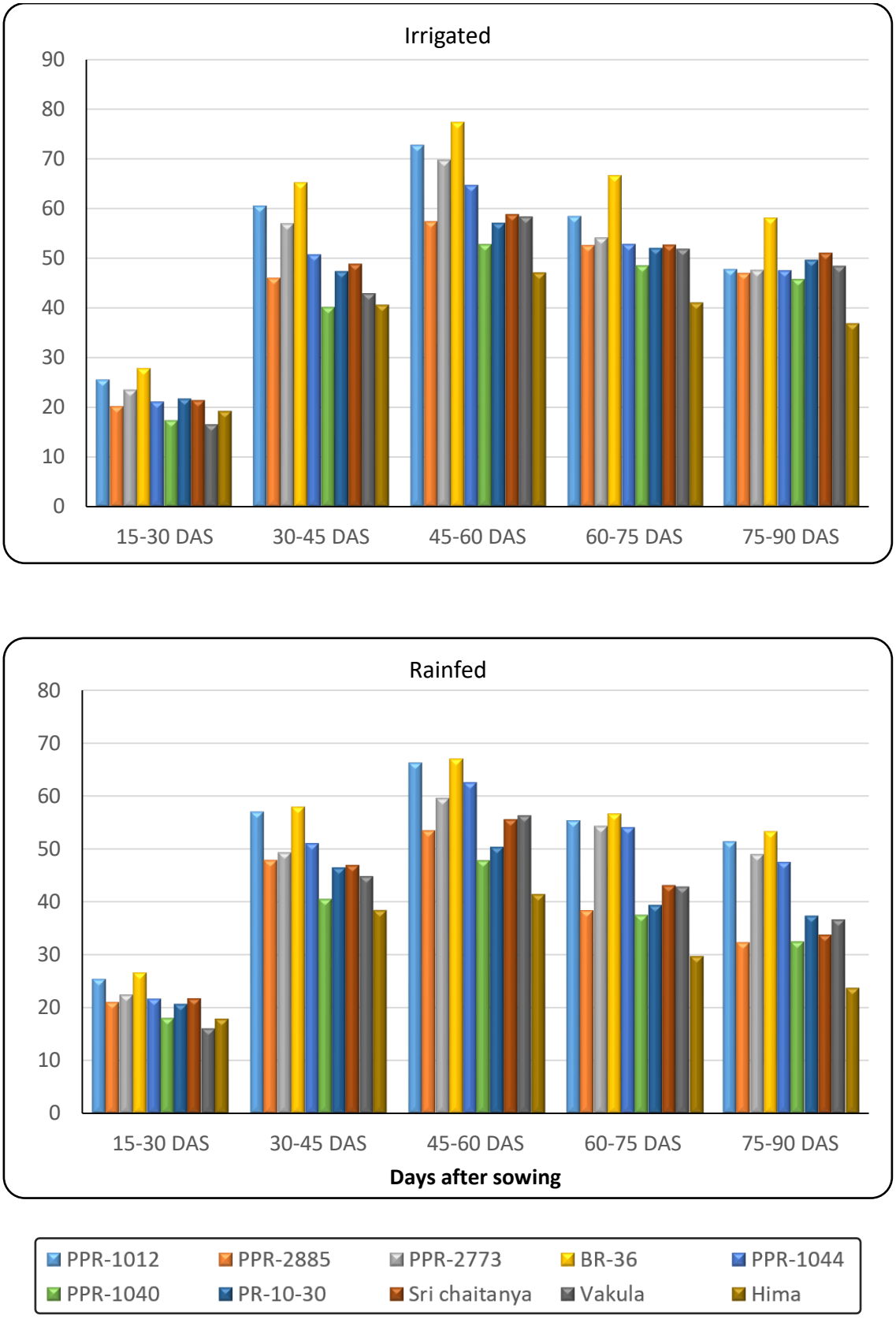


Fig. 4.8. Evaluation of ragi genotypes for leaf area duration under rainfed conditions

4.3 DROUGHT TOLERANCE TRAITS

4.3.1 Water Use Efficiency

4.3.1.1 Specific leaf area (cm^2 g^{-1})

The specific leaf area of ragi genotypes as influenced by rainfed and irrigated conditions are presented in Table 4.9 and Fig. 4.9.

The SLA is often considered as an indirect measure of leaf expansion and is the ratio of leaf area to its dry weight. If SLA is lesser, the leaf thickness would be more and hence the capacity of photosynthesis would be more with lesser transpiration. Hence, this trait is considered as potential for measuring WUE of genotypes.

The data reveals that significant differences in SLA were observed between rainfed treatments, at 60 DAS and 75 DAS. However, differences among genotypes and their interaction effects were non significant. Talwar *et al*. (2004) and Latha and Reddy (2007) also reported a significant genotypic differences for SLA among groundnut.

Due to moisture stress from 47 DAS to 67 DAS in rainfed treatment SLA was significantly decreased at 60 DAS(91.19 cm^2 g^{-1}) compared to control (118.03 cm^2 g^{-1}).Such significant differences in SLA among ragi genotypes under moisture stress conditions was reported by Venkatesh Babu *et al.* (2015).

The genotype BR-36, PPR-1012 and PPR 2773 maintained numerically higher SLA values compared to all other genotypes. Hima being short statured genotype recorded low SLA in irrigated as well as rainfed treatments. Though there is significant variability among irrigated and rainfed treatments, genotypic variability is nonsignificant. Such variability would have occurred due to increased leaf thickness among the genotypes as drought avoidance mechanism. Nobel, (1991) also opined that water deficit

Table 4.9. Evaluation of ragi genotypes for specific leaf area (cm^2 g^{-1}) under rainfed conditions

Genotype	45 DAS			60 DAS			75 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	182.17	155.23	168.70	135.17	102.12	118.65	82.13	67.46	74.80
PPR-2885	148.66	160.76	154.71	112.50	83.96	98.23	66.08	50.79	58.44
PPR-2773	183.74	132.14	157.94	126.93	99.29	113.11	76.01	72.88	74.45
BR-36	136.27	139.39	137.83	130.50	106.15	118.32	80.38	83.62	82.00
PPR-1044	168.25	146.20	157.23	125.67	94.32	109.99	80.29	65.14	72.72
PPR-1040	128.89	148.15	138.52	110.26	89.18	99.72	63.94	63.05	63.50
PR-10-30	132.71	118.57	125.64	107.12	78.46	92.79	67.51	63.25	65.38
Sri chaitanya	152.82	142.83	147.82	126.79	87.43	107.11	72.12	68.53	70.33
Vakula	125.86	136.41	131.13	113.24	91.96	102.60	66.24	64.58	65.41
Hima	130.70	126.63	128.66	92.16	79.02	85.59	54.30	43.59	48.95
Mean	**149.00**	**140.63**		**118.03**	**91.19**		**70.9**	**64.29**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**8.4348**	**18.8608**	**26.6731**	**3.7376**	**8.3575**	**11.8193**	**1.9722**	**4.41**	**6.2367**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**10.7032**	**N.S**	**N.S**	**5.6478**	**2.7892**	**N.S**

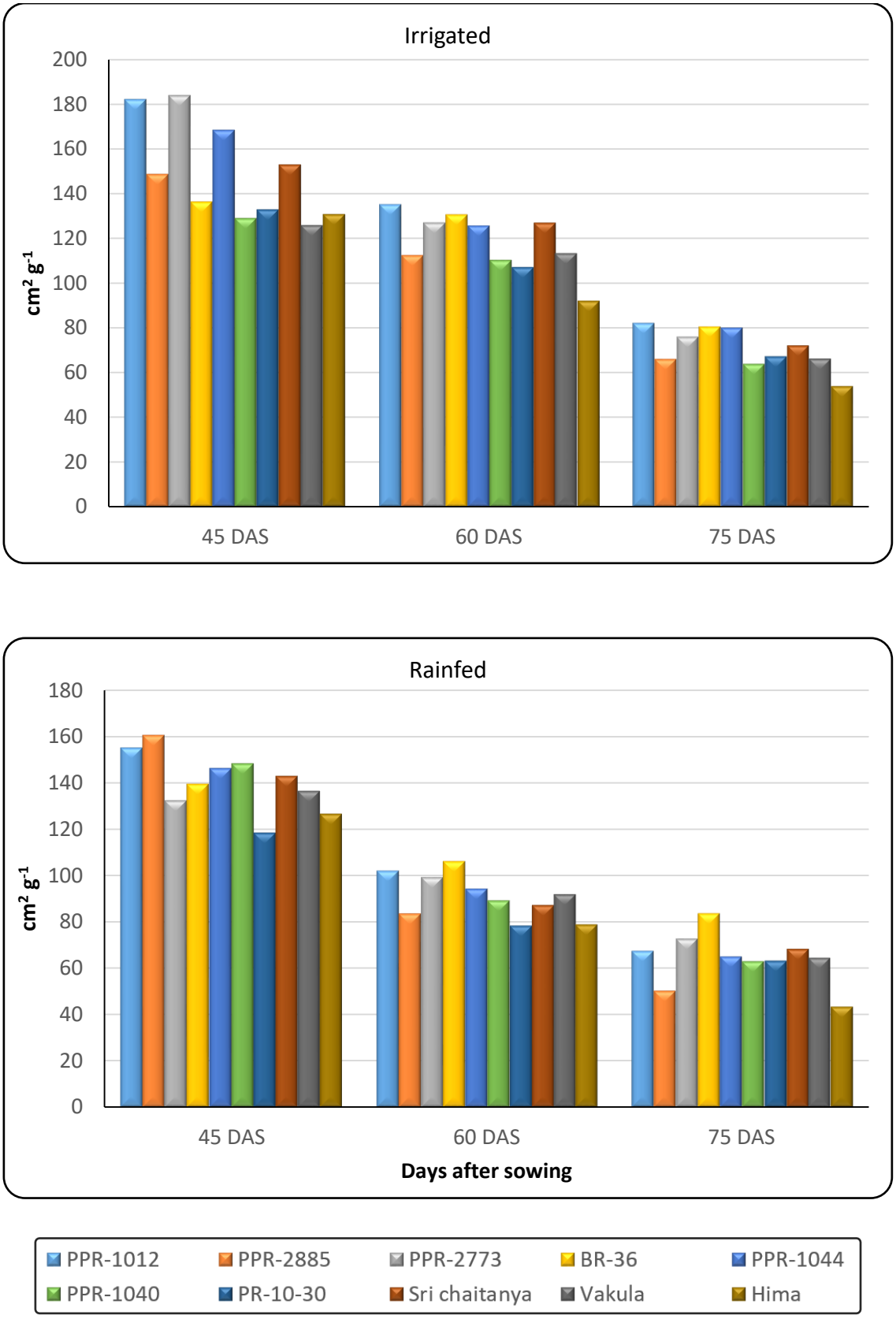


Fig. 4.9. Evaluation of ragi genotypes for specific leaf area (cm^2 g^{-1}) under rainfed conditions

may influence leaf thickness by increasing number of chlorenchyma cells and chloroplasts per unit leaf surface area.

4.3.1.2 SPAD Chlorophyll Meter Reading

SPAD chlorophyll meter reading (SCMR) of ragi genotypes were recorded in both rainfed and irrigated treatments and presented in Table 4.10 and Fig. 4.10.

SPAD meter quantifies the greenness or relative chlorophyll content of leaves. The SCMR is an indication of leaf nitrogen status, since SLN (Specific leaf nitrogen) determines the differences in WUE, it can be visualized that SCMR could reflect well in WUE differences (Veeraputhian *et al.* 2001).

Significant differences were observed among treatments and genotypes at 60 DAS. At 75 DAS significant differences were recorded only between genotypes, but not between irrigated and rainfed treatments. However their interaction effects were non significant. The reduction in SCMR values due to rainfed condition is 15.4 per cent at 60 DAS and 3.34 per cent at 75 DAS. Reduction in SCMR values, attributed to reduction in chlorophyll content under moisture stress conditions in ragi (Maqsood and Azam Ali, 2007) and in aerobic rice (Devi *et al*., 2013).

Among the genotypes tested, BR-36 recorded highest mean SCMR (37.85) followed by PPR-1012 (33.95), PPR-2773 (32.91) at 60 DAS compared to other genotypes. These genotypes maintained higher SCMR values in spite of moisture stress due to rainfed condition between 35 to 65 DAS. Similar significant differences between genotypes under irrigated as well as moisture stress were reported in ragi (Maqsood and Azam Ali 2007) and in rice Devi *et al.* (2013).

Table 4.10. Evaluation of ragi genotypes for SCMR values under rainfed conditions

Genotype	45 DAS			60 DAS			75 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	33.20	32.89	33.05	35.73	32.16	33.95	31.18	28.23	29.71
PPR-2885	31.30	30.12	30.71	34.43	29.47	31.95	28.73	26.30	27.52
PPR-2773	32.10	32.09	32.10	35.03	30.78	32.91	30.80	29.96	30.38
BR-36	34.40	34.26	34.33	40.63	35.07	37.85	34.44	31.18	32.81
PPR-1044	30.07	29.87	29.97	34.50	29.30	31.90	30.05	25.81	27.93
PPR-1040	31.83	30.00	30.92	32.55	27.56	30.06	24.92	27.74	26.33
PR-10-30	30.93	29.93	30.43	32.27	28.18	30.23	26.56	26.30	26.43
Sri chaitanya	30.77	30.25	30.51	33.00	28.17	30.59	25.70	27.90	26.80
Vakula	30.93	30.88	29.41	35.80	31.46	33.63	29.97	28.89	29.43
Hima	28.07	27.02	27.55	31.67	28.96	30.32	24.71	22.13	23.42
Mean	**31.36**	**30.73**		**34.56**	**30.11**		**28.70**	**27.74**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.8466**	**1.893**	**2.6771**	**0.9686**	**2.1658**	**3.0629**	**0.6323**	**1.4139**	**1.9995**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**2.7737**	**N.S**	**N.S**	**N.S**	**4.0489**	**N.S**

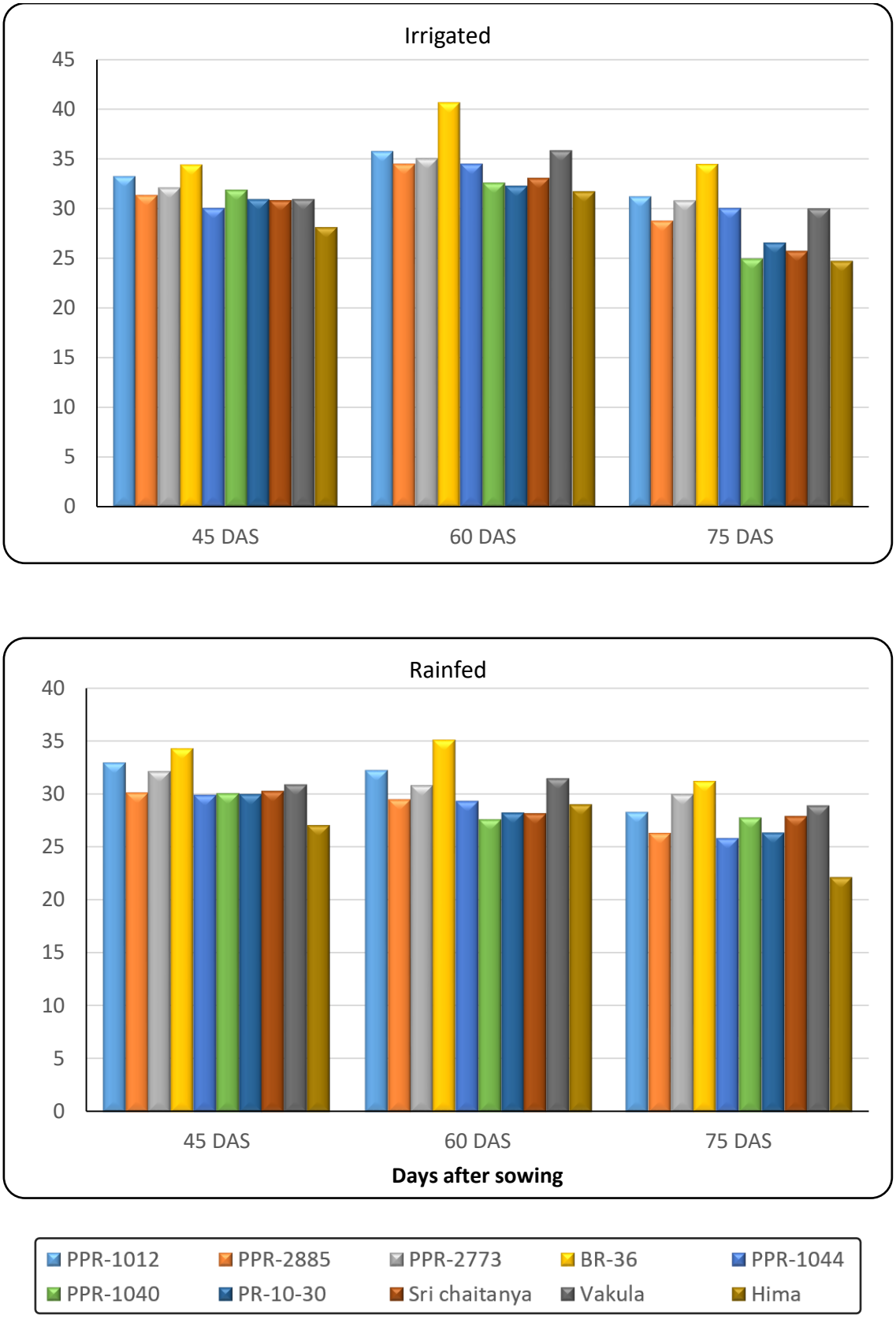


Fig. 4.10. Evaluation of ragi genotypes for SCMR values under rainfed conditions

A significant positive correlation between SCMR and WUE was considered as good drought tolerant trait and was established in groundnut (Rao *et al*., 2001) and ragi (Venkatesh Babu *et al.*, 2015). Hence BR-36 and PPR-1012 genotypes considered to possess high drought tolerance compared to other genotypes, as they possess moderate SLA and high SCMR values.

4.3.2 Other Drought Tolerant Traits

4.3.2.1 Chlorophyll Stability Index

The chlorophyll stability index (CSI), as affected by moisture stress from panicle initiation to grain filling stage among ragi genotypes are presented in Table 4.11 and Fig. 4.11.

The chlorophyll stability index is an indication of the stress tolerance capacity of plants. A high CSI value means that the stress did not have much effect on chlorophyll content of plants.

Significant differences were observed among the cultivars and treatments. Due to moisture stress CSI decreased significantly. The extent of decrease was 4.77 per cent when compared to irrigated control. Similar reduction in CSI value under moisture stress conditions were reported by Parihar *et al.* (2012) in maize.

Under heat stress condition at 40, the chlorophyll a, b and total chlorophyll content declined significantly in the present study, suggesting structural damage to the chloroplast in sorghum seedlings due to high temperature. The reduction in chlorophyll content was found in drought susceptible genotypes as compared to drought tolerant and wild sorghum genotypes. The decrease in chlorophyll a, b and total chlorophyll content in response to induced heat stress.

Table 4.11. Evaluation of ragi genotypes for chlorophyll stability index under rainfed conditions

Genotype	45 DAS			60 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	85.295	83.209	84.25	85.153	78.047	81.60
PPR-2885	80.467	82.657	81.56	84.195	77.465	80.83
PPR-2773	83.731	80.858	82.29	84.771	78.509	81.64
BR-36	88.604	85.670	87.14	86.163	81.177	83.67
PPR-1044	88.993	88.673	88.83	84.552	76.648	80.60
PPR-1040	81.191	84.246	82.72	83.804	73.336	78.57
PR-10-30	82.290	82.261	82.28	80.689	70.491	75.59
Sri chaitanya	87.09	86.231	86.66	79.425	71.855	75.64
Vakula	88.566	87.851	88.21	84.563	77.397	80.98
Hima	83.456	82.942	83.20	78.190	71.43	74.81
Mean	**84.968**	**84.549**		**83.15**	**75.64**	
	T	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**1.2741**	**2.8491**	**4.0292**	**1.7846**	**3.9904**	**5.6433**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**5.1104**	**N.S**	**N.S**

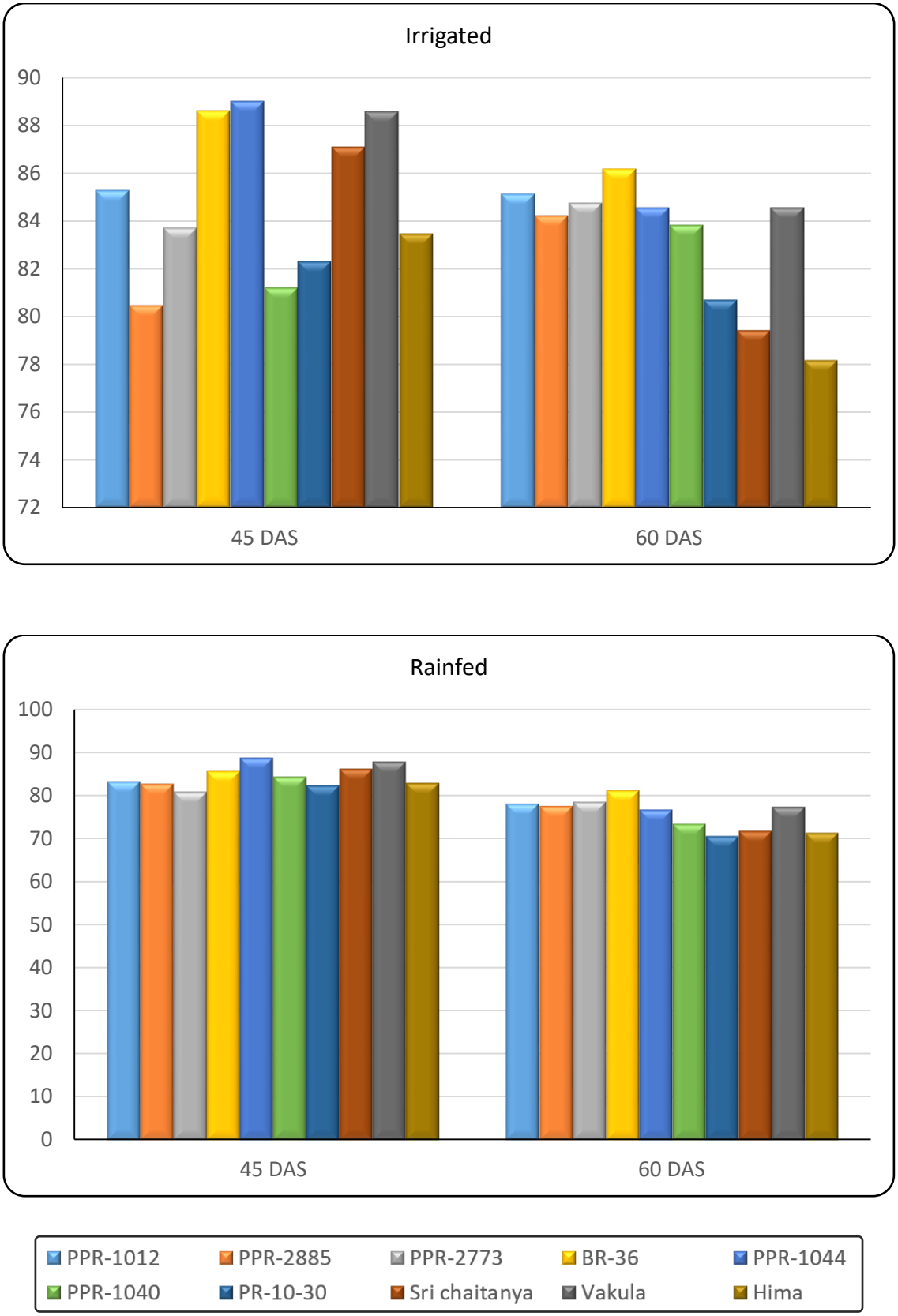


Fig. 4.11. Evaluation of ragi genotypes for chlorophyll stability index under rainfed conditions

The genotypes BR-36, PPR-1012, PPR-2773 maintained significantly high values of CSI compared to other genotypes both under irrigated and moisture stress conditions. A higher CSI helps in with standing stress through better availability of chlorophyll (Meghanatha Reddy *et al*, 2007).

A higher CSI helps the plants to withstand stress through better availability of chlorophyll. This leads to increased photosynthetic rate, more dry matter production and higher productivity as it was noticed in the genotypes BR-36 and PPR-1012.

4.3.2.2 Relative water content (%)

Relative Water Content (RWC) of ragi genotypes were recorded in both rainfed and irrigated treatments at 45 DAS, 60 DAS and 75 DAS and presented in Table 4.12 and Fig. 4.12.

Relative water content is considered as a measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful index for dehydration tolerance. RWC showed significant differences between treatments at 60 DAS and 75 DAS and only numerical differences were recorded between genotypes and their interactions. Similar significant differences between genotypes under irrigated as well as moisture stress was reported in wheat (Moaed Almeselmani *et al.,* 2012) rabi sorghum (Surwenshi *et al*., 2010) and rice (Devi *et al*., 2013).

A decrease in the relative water content (RWC) in response to drought stress has been noted in wide variety of plants as reported by Nayyar and Gupta (2006) that when leaves are subjected to drought, leaves exhibit large reductions in RWC and water potential. Exposure of plants to drought stress substantially decreased the leaf water potential, relative water content and transpiration rate, with a concomitant increase in leaf temperature (Siddique *et al.,* 2001).

Table 4.12. Evaluation of ragi genotypes for relative water content (%) under rainfed conditions

Genotype	45 DAS			60 DAS			75 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	90.47	89.85	90.16	91.59	79.44	85.52	89.6	**87.30**	88.45
PPR-2885	89.43	86.88	88.16	90.71	73.29	82.00	89.8	**88.70**	89.25
PPR-2773	90.16	88.86	89.51	91.21	77.89	84.55	86.2	**87.20**	86.7
BR-36	91.74	90.11	90.93	91.77	79.03	85.40	90.1	**92.20**	91.15
PPR-1044	89.94	84.52	87.23	90.56	63.56	77.06	88.3	**87.00**	87.65
PPR-1040	87.45	85.86	86.66	91.21	77.89	84.55	89.7	**88.90**	89.3
PR-10-30	86.22	88.66	87.44	90.63	71.33	80.98	89.4	**90.20**	89.8
Sri chaitanya	87.28	86.12	86.70	90.01	71.77	80.89	88.1	**87.60**	87.85
Vakula	89.93	86.05	87.99	91.20	78.23	84.72	88.8	**88.90**	88.85
Hima	87.77	86.12	86.95	89.74	65.41	77.58	86.6	**85.40**	86
Mean	**89.04**	**87.30**		**90.86**	**73.88**		**88.66**	**88.34**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**1.7752**	**3.9696**	**5.6138**	**1.4021**	**3.1352**	**4.4338**	**2.1603**	**4.8305**	**6.8314**
C.D (P=0.05)	**N.S**	**N.S**	**N.S**	**4.0151**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

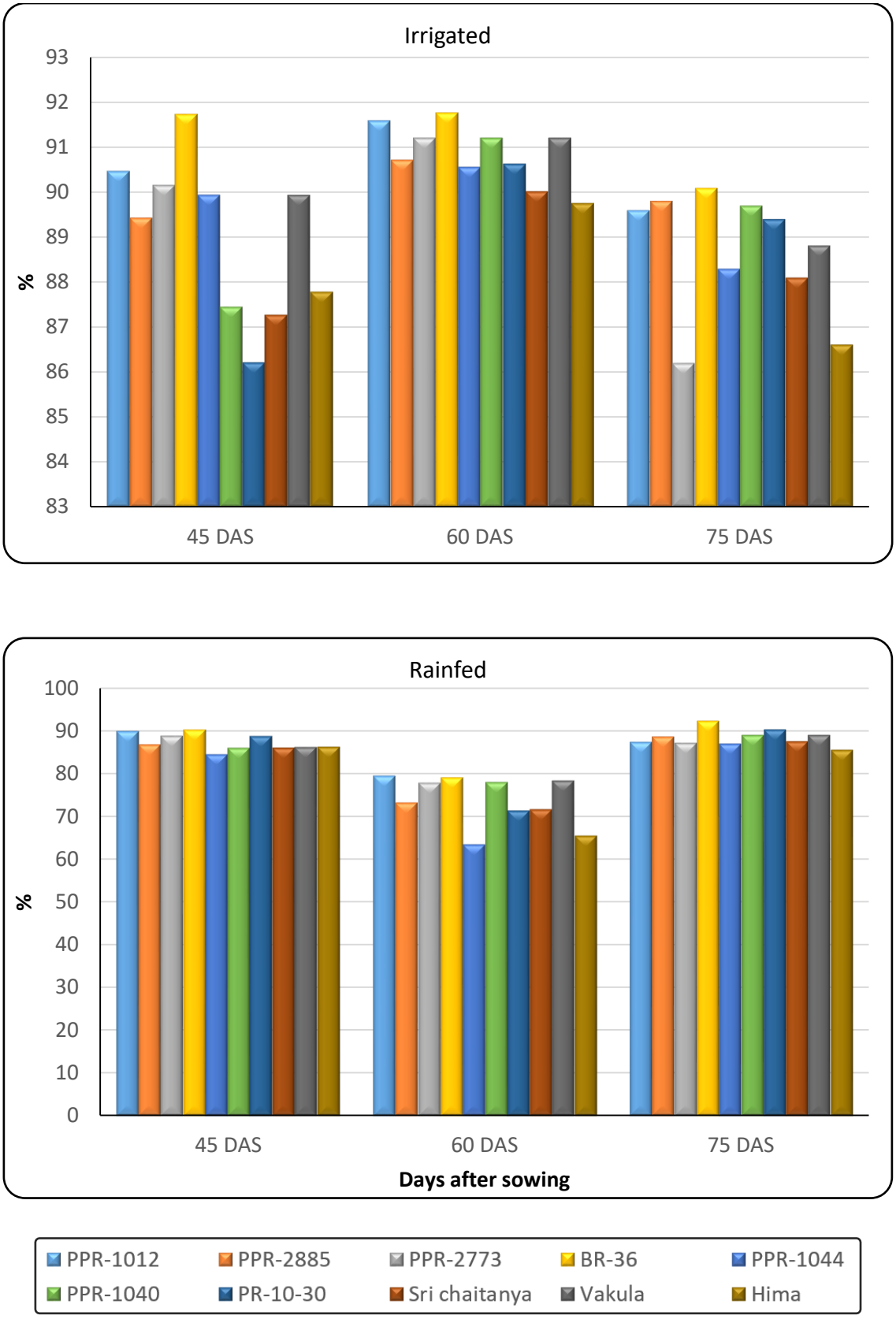


Fig. 4.12. Evaluation of ragi genotypes for relative water content (%) under rainfed conditions

Due to dryspell between 47-67 DAS, RWC was significantly decreased in rainfed treatment to the extent of decrease was 18.68 per cent compared to control at 60 DAS. However at 75 DAS differences were insignificant as rain was received after 65 DAS. Such decrease in RWC values under water stress conditions was also reported in wheat by Tatar and Gevrek (2008) and Kameli and Losel (1996), in groundnut by Latha (2004) and in rice by Devi (2013).

This deviation in RWC may be attributed to differences in the ability of the variation to absorb more water from the soil and or the ability to control water loss through the stomata. These findings are in agreement with those reported by Sinclair and Ludlow (1985).

The genotype BR-36 recorded highest RWC values followed by PPR-1012 and PPR-2773 compared to all other genotypes and lowest is Hima during moistures stress conditions. Hence BR-36, PPR-1012 and PPR-2773 maintained higher tissue water status in moisture stress condition, as they recorded more extension of root growth compared to other genotypes. This may be the prime reason for the high physiological efficiency of these genotypes under rainfed conditions. Similar results were obtained by Moaed Almeselmani *et al.* (2012) highest value of RWC was recorded in the drought tolerant durum wheat varieties compared to others at vegetative and anthesis stage under rainfed conditions.

4.3.2.3 Root length (cm)

Root length of ragi genotypes were recorded in both rainfed and irrigated treatments at 15 days interval and presented in Table 4.13 and Fig. 4.13.

Narayan and Mishra (1989) recorded deeper penetration of root under moisture stress, and concluded that depth of root penetration could serve as an important selection criterion for screening cultivars for drought resistance.

Table 4.13. Evaluation of ragi genotypes for root length (cm) under rainfed conditions

Genotype	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			90 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	7.92	6.78	7.35	10.21	10.00	10.11	12.19	12.00	12.10	17.69	**23.97**	20.83	25.45	23.43	24.44	25.80	27.15	26.48
PPR-2885	7.07	6.84	6.95	9.77	8.91	9.34	11.35	11.30	11.32	16.92	**16.41**	16.67	19.49	24.32	21.90	20.09	18.79	19.44
PPR-2773	7.21	6.39	6.80	10.05	9.31	9.68	11.93	10.84	11.39	17.63	**21.28**	19.46	22.74	21.89	22.32	21.32	26.39	23.85
BR-36	8.32	8.09	8.20	10.97	10.12	10.55	12.77	11.67	12.22	19.48	**18.96**	19.22	28.97	23.97	26.47	28.53	22.78	25.66
PPR-1044	6.84	7.74	7.29	8.76	7.55	8.16	11.65	11.65	11.65	15.33	**16.49**	15.91	21.46	20.89	21.17	23.98	19.89	21.93
PPR-1040	6.63	5.83	6.23	9.89	9.34	9.61	11.14	10.56	10.85	16.87	**17.63**	17.25	20.60	17.14	18.87	21.85	21.68	21.77
PR-10-30	7.82	8.83	7.35	8.56	7.44	8.00	12.78	11.57	12.17	16.21	**17.99**	17.10	22.38	24.34	23.36	24.66	25.38	24.02
Sri chaitanya	6.87	6.01	6.95	8.99	7.42	8.21	11.59	12.29	11.94	14.04	**18.94**	16.49	19.44	32.42	25.93	22.15	20.24	21.20
Vakula	6.79	5.62	6.80	7.77	6.95	7.36	11.67	10.96	11.32	14.14	**16.90**	15.52	18.17	18.17	18.17	19.50	19.33	19.42
Hima	5.47	5.07	8.20	5.98	5.69	5.84	10.00	9.95	9.98	13.90	**17.59**	15.75	17.91	19.59	18.75	18.53	17.13	17.83
Mean	**7.09**	**6.72**		**9.095**	**8.273**		**11.70**	**11.279**		**16.22**	**18.62**		**21.66**	**22.62**		**22.44**	**21.88**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.2294**	**0.5129**	**0.7253**	**0.3879**	**0.8674**	**1.2266**	**0.3601**	**0.8053**	**1.1389**	**1.1464**	**2.5635**	**3.6254**	**1.0233**	**2.2882**	**3.2360**	**0.884**	**1.9866**	**2.8095**
C.D (P=0.05)	**N.S**	**1.4687**	**N.S**	**N.S**	**2.4839**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

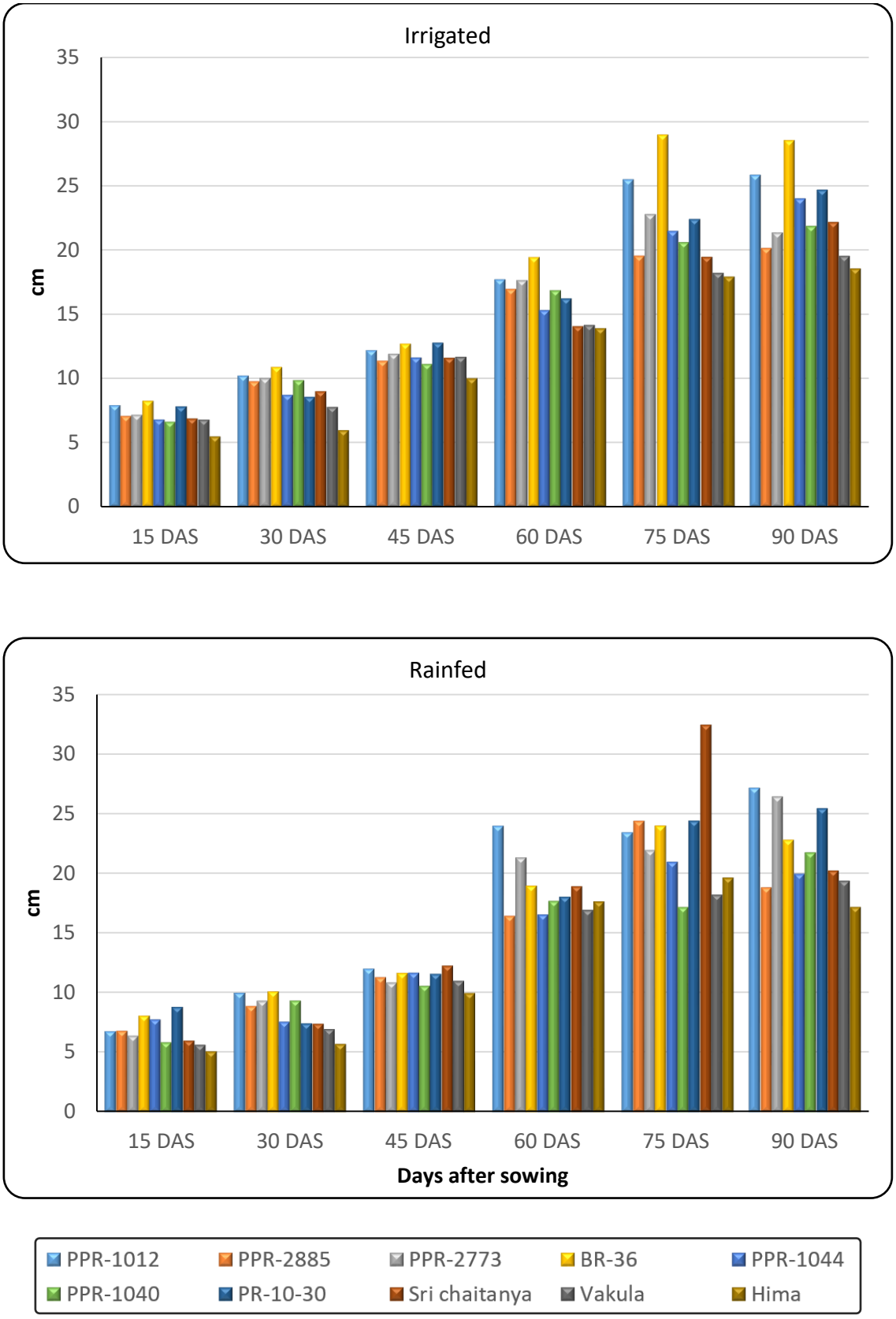


Fig. 4.13. Evaluation of ragi genotypes for root length (cm) under rainfed conditions

Significant differences were not observed between genotypes, treatments and interactions throughout the duration, except initial differences between genotypes 15 and 30 DAS.

Among the genotypes BR-36 recorded numerically higher root length values followed by PPR-1012 and PPR-2773 compared to all other genotypes especially under rainfed treatments. Boyer, (1996) identified deep root system as the targeted for drought tolerance improvement. Production of root system under drought is very important and had good correlation with yield under moisture stress (Darofeev and Tyselano, 1982).Root trait, though very important with regard to drought tolerance many times significant differences will not be seen mainly due to lack of accuracy in obtaining entire root length and difficulty in reading.

4.3.2.4 Proline content (µg g^{-1})

Proline content of fresh leaves of ragi genotypes was recorded at 45 and 60 DAS and presented in Table 4.14 and Fig. 4.14.

Accumulation of proline has been advocated as a parameter of selection for stress tolerance. Proline accumulation can be met with the moisture stress. High levels of proline enabled the plant to maintain low water potentials. Proline accumulation is often considered to be involved in stress resistance mechanisms (Ramanjulu and Sudhakar, 2000).

Leaf proline content varied significantly among treatments, genotypes and their interaction at 60 DAS when there was a dry spell. Under rainfed condition mean proline content was increase by 11.3%. Nisha Kataria *et al*. (2014) reported that in mungbean under stress condition, the decrease in osmotic potential was mainly due to the accumulation of solutes like proline and soluble carbohydrates.

Table 4.14. Evaluation of ragi genotypes for proline content (µg g^{-1}) under rainfed conditions

Genotype	45 DAS			60 DAS		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	0.343	0.113	0.228	0.688	0.748	0.718
PPR-2885	0.230	0.073	0.152	0.548	0.475	0.512
PPR-2773	0.355	0.262	0.309	0.628	0.532	0.580
BR-36	0.227	0.240	0.234	0.502	0.768	0.635
PPR-1044	0.157	0.130	0.144	0.373	0.463	0.418
PPR-1040	0.255	0.250	0.253	0.373	0.470	0.422
PR-10-30	0.235	0.257	0.246	0.300	0.353	0.327
Sri chaitanya	0.342	0.292	0.317	0.337	0.358	0.348
Vakula	0.327	0.303	0.315	0.585	0.713	0.649
Hima	0.283	0.317	0.300	0.340	0.390	0.365
Mean	**0.275**	**0.224**		**0.467**	**0.527**	
	T	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.023**	**0.0513**	**0.0726**	**0.017**	**0.038**	**0.0537**
CD(P=0.005)	**N.S**	**N.S**	**N.S**	**0.0486**	**0.1087**	**0.154**

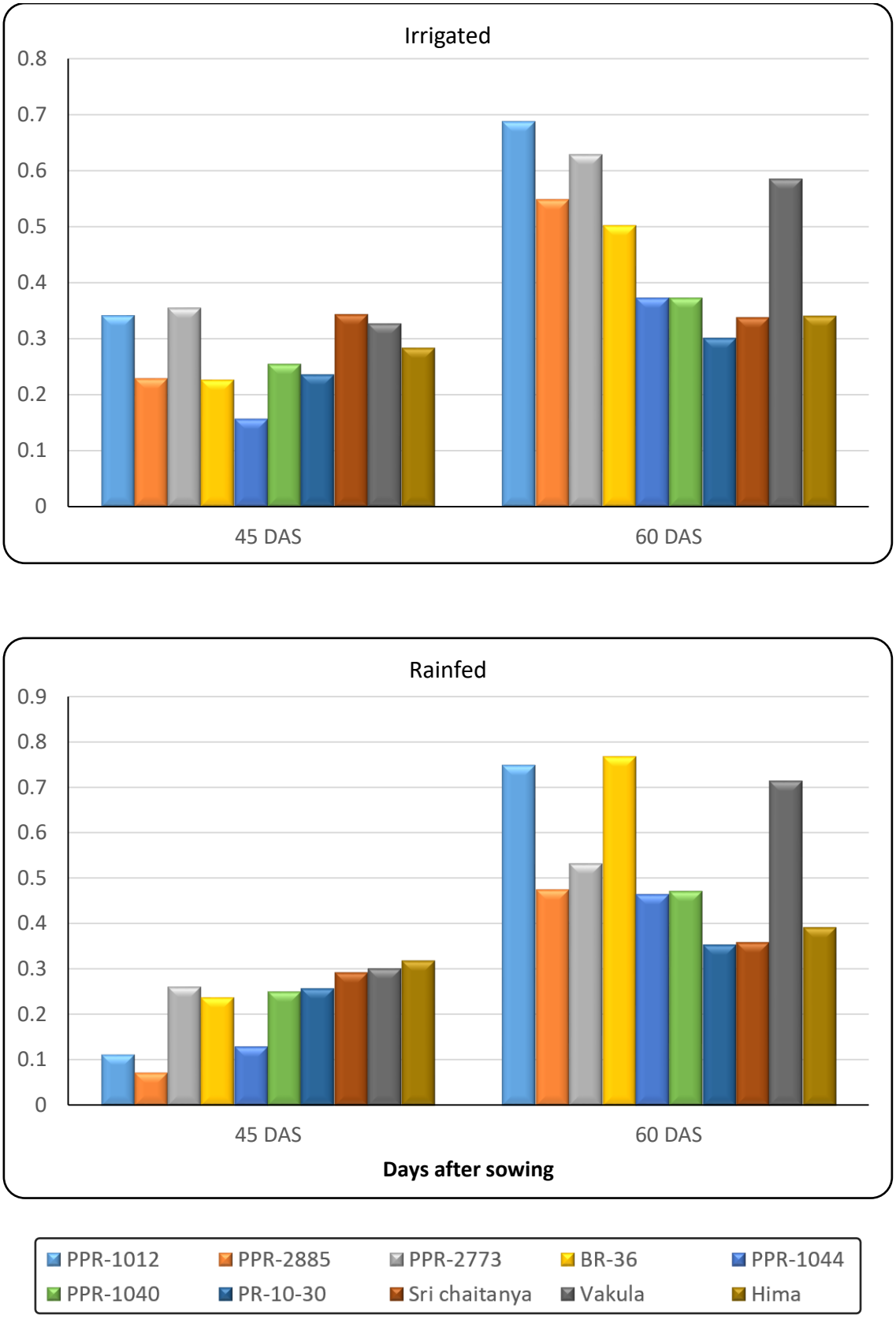


Fig. 4.14. Evaluation of ragi genotypes for proline content under rainfed conditions

Among the genotypes BR-36 recorded highest proline values followed by PPR-1012 and PPR-2773 compared to all other genotypes and lowest is Hima during moistures stress conditions. If denotes the drought tolerance capacity of these three genotypes. Accumulation of proline content under water stress indicates accumulated proline might act as a compatible solute regulating and reducing water loss from the plant cell during water deficit (Yokota *et al*., 2006) and play important role in osmosis balance (Fedina *et al*., 2002). Thus, the proline content is a good indicator for screening drought tolerant varieties in water stress condition (Bayoumi *et al*., 2008 and Kumar *et al*., 2011).

4.4 YIELD AND YIELD COMPONENTS

Yield in crop plants is an ultimate expression and depends upon the expressibility of many other characters called yield components.

4.4.1 Number of Tillers per Plant

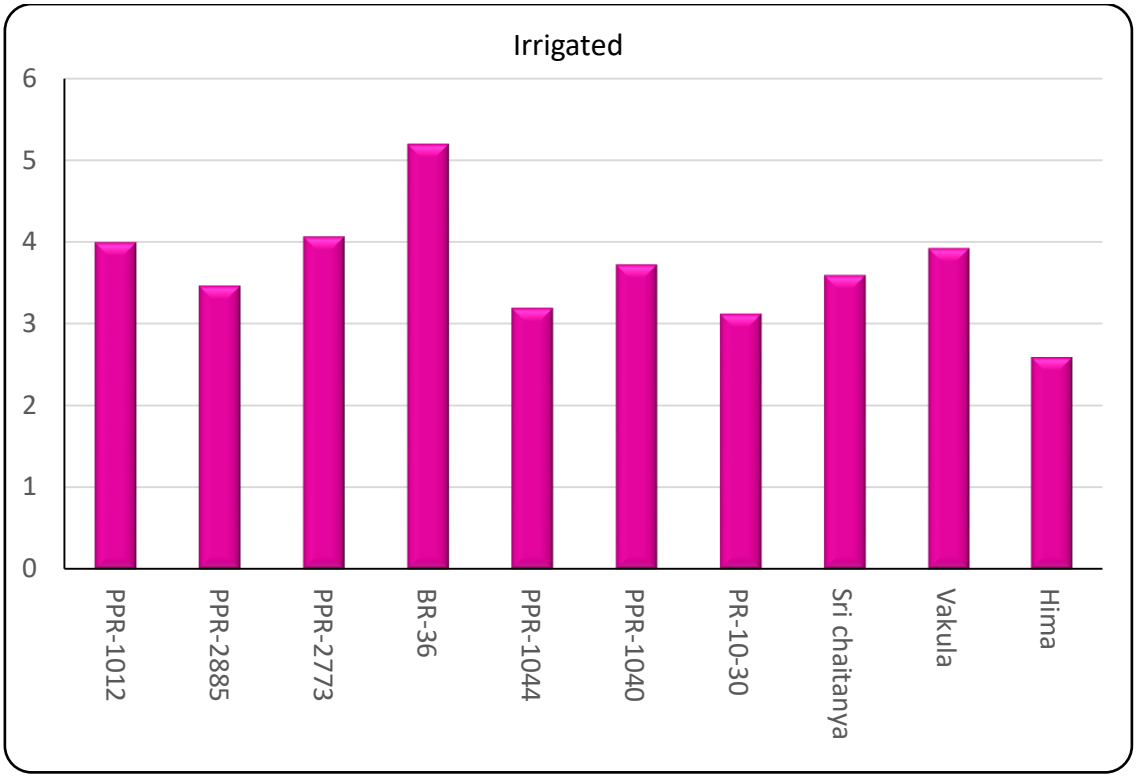
Number of tillers per plant recorded at harvest in ragi genotypes as influenced by rainfed and irrigated treatments are presented in Table 4.15 and Fig. 4.15.

Significant differences were noticed between moisture stress treatments, genotypes and their interactions. The number of tillers per plant is considered as one of the important morphological characters directly associated with yield in millets (Acharya, 1987, Chidambaram and Palanisamy, 1996).

Another important yield contributing parameter in many tillering cereals is the number of productive tillers. Reduction in this parameter under stress conditions has been noticed in wheat, barley and paddy (Fischer, 1963). In finger millet, contribution to yield by tillers is estimated to be 37 per cent (Mahadevappa and Ponnaiya, 1962).

Table 4.15. Evaluation of ragi genotypes for yield components under rainfed conditions

Genotype	No. of tillers per plant			No. of fingers per plant			1000 grain weight (g)		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	4.00	4.07	4.04	19.53	15.99	17.76	2.62	2.43	2.53
PPR-2885	3.47	2.93	3.20	18.67	15.77	17.22	1.96	1.84	1.90
PPR-2773	4.07	4.08	4.08	19.27	16.65	17.96	2.51	2.87	2.69
BR-36	5.20	4.13	4.67	19.93	17.94	18.94	2.74	2.55	2.65
PPR-1044	3.20	2.67	2.94	17.47	15.54	16.51	2.39	2.26	2.33
PPR-1040	3.73	2.67	3.20	15.27	14.98	15.13	1.95	1.60	1.78
PR-10-30	3.13	3.20	3.17	16.53	13.63	15.08	2.10	2.02	2.06
Sri chaitanya	3.60	2.87	3.24	16.07	14.28	15.18	2.33	2.51	2.42
Vakula	3.93	3.33	3.93	17.73	14.94	16.34	2.40	2.04	1.94
Hima	2.60	2.40	2.50	12.07	9.33	10.70	1.64	1.60	1.62
Mean	**3.693**	**3.224**		**17.254**	**14.905**		**2.22**	**2.16**	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.1783**	**0.3988**	**0.5639**	**0.5348**	**1.1958**	**1.6912**	**0.087**	**0.196**	**0.277**
CD(P=0.005)	**N.S**	**1.1419**	**N.S**	**1.5315**	**3.4245**	**N.S**	**N.S**	**0.562**	**N.S**



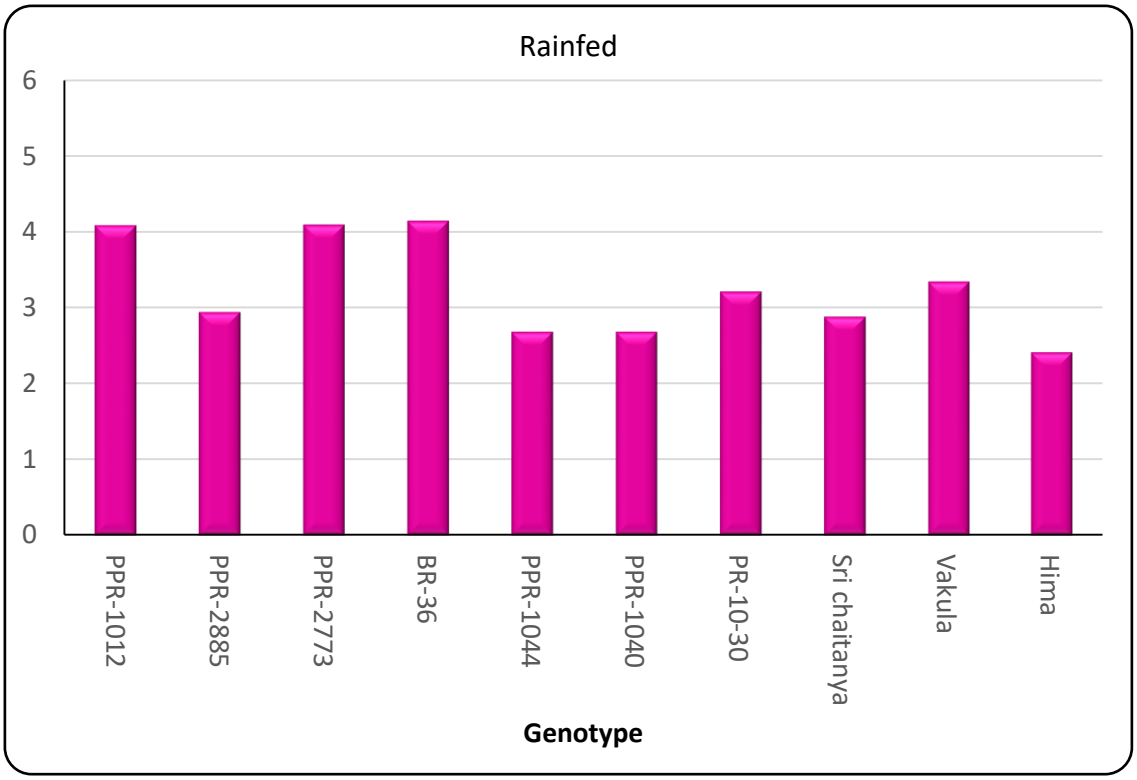


Fig. 4.15. Evaluation of ragi genotypes for no. of tiller per plant under rainfed conditions

Imposition of moisture stress from panicle initiation to grain filling stage significantly reduced number of tillers per plant compared to irrigated control. The extent of decrease was 12.73 per cent at 60 DAS compared to irrigated control. Similar results have already been reported in a number of studies that have shown reduction in number of tillers caused by drought stress in pearl millet (Mahalakshmi and Bidinger, 1985).

The reduction in number of tillers is an adaptive mechanism that has been induced in response to water stress. This reduction reduces the transpiration area and hence helps the plant to withstand against water stress.

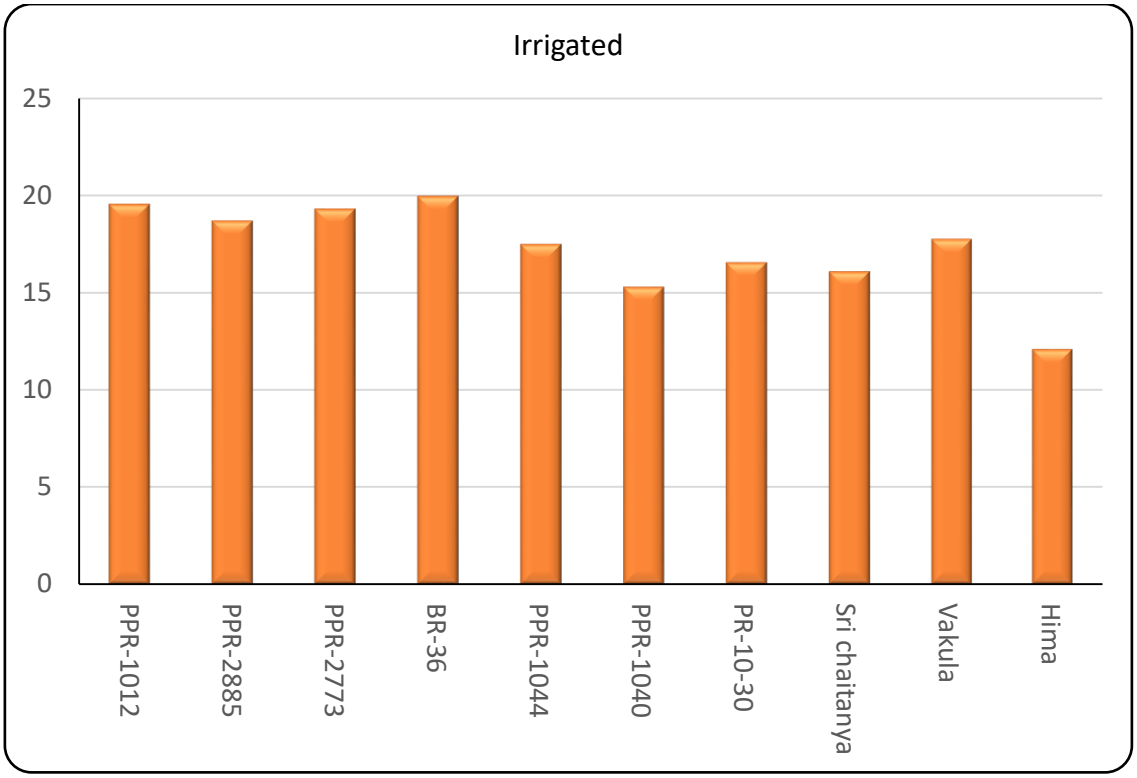
Among the genotypes, irrespective of irrigation and moisture stress treatments, BR-36, PPR-1012 and PPR-2773 recorded significantly higher number of tillers per plant compared to other genotypes. PPR-2885, PPR-1044, PPR-1040, PR-10-30, Srichaitanya and Vakula recorded moderate number of tillers per plant, where as Hima and PPR-1044 recorded lowest number of tiller per plant.

4.4.2 Number of Fingers per Plant

Number of fingers per plant recorded in ragi genotypes as influenced by rainfed and irrigated treatments are presented in Table 4.15 and Fig. 4.16.

Significant differences were recorded between moisture stress treatments, genotypes and their interactions. Similar to number of tillers per plant, fingers per panicle were also significantly reduced due to imposition of stress at panicle initiation stage, denoting the fact that number of fingers is affected irrespective of moisture stress. The reduction in number of fingers per panicle was 13.62 per cent at 60 DAS compared to irrigated control.

The genotypes tested were also significantly varied for number of fingers per panicle and recorded similar results compared to number of



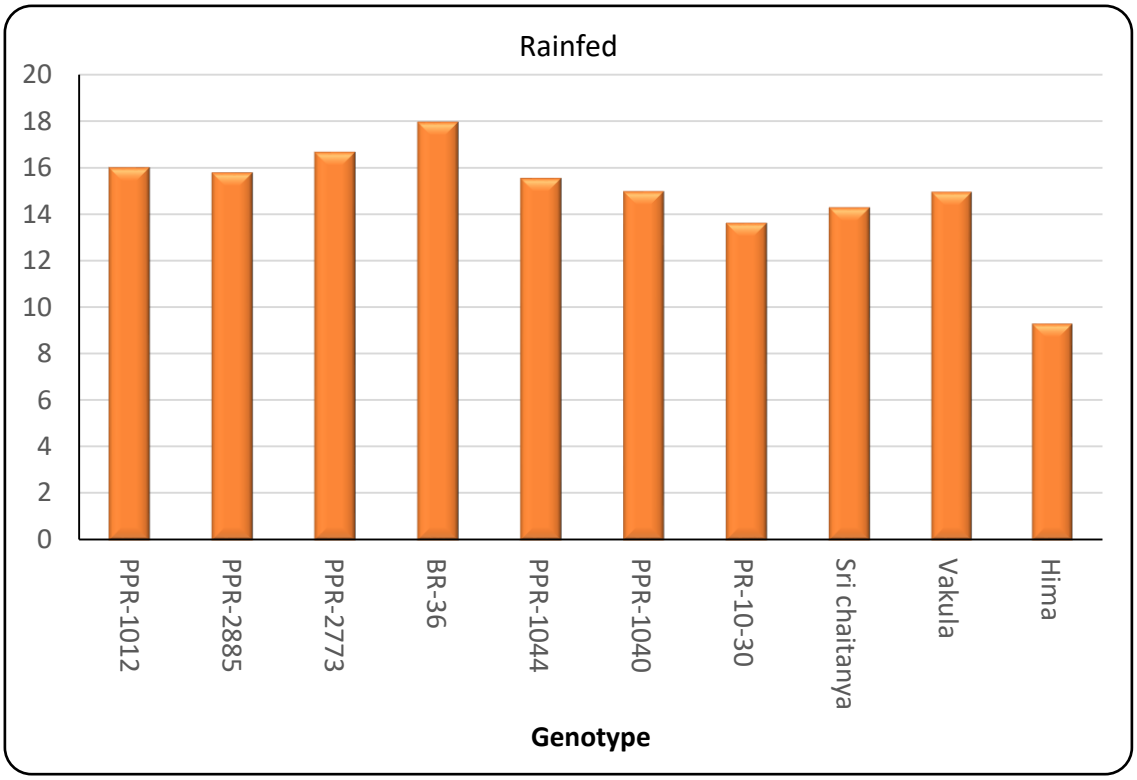


Fig. 4.16. Evaluation of ragi genotypes for no. of fingers per plant under rainfed conditions

tillers per plant. Among the genotypes, BR-36 recorded highest mean number of fingers per panicle (18.94) followed by PPR-2773 (17.96) and PPR-1012(17.76). PPR-2885, PPR-1044, PPR-1040, PR-10-30 and Vakula recorded moderate number of fingers per panicle where as Hima(10.70) recorded lowest number of fingers per panicle under irrigated and stress treatments.

4.4.3 1000-grain Weight (g)

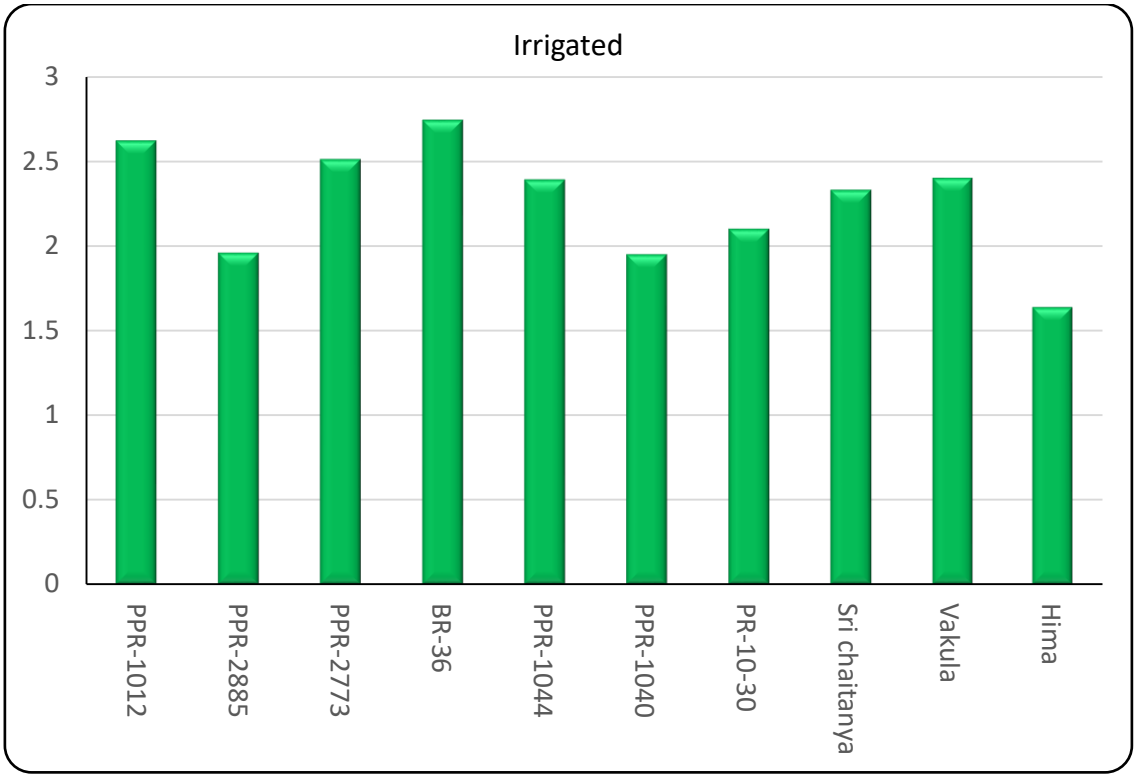
1000-grain weight recorded in ragi genotypes as influenced by rainfed and irrigated treatments are presented in Table 4.15 and Fig. 4.17.

Significant differences were noticed between moisture stress treatments, genotypes and their interactions. Moisture stress at 47-67 DAS decreased 1000-grain weight (2.70%) compared to irrigated control. Such decrease in 1000-grain weight of ragi genotypes due to moistures stress was reported by Maqsood and Azam Ali (2007).

The genotypes which recorded high drought tolerant traits i.e. BR-36, PPR-1012, PPR-2773 recorded highest 1000-grain weight. PPR-1044, PR-10-30, Vakula, Sri Chaitanya recorded moderate 1000-grain weight, where as PPR-1040 and Hima recorded significantly low 1000-grain weight.

This is likely due to the shortage of moistures which forces plant to complete its grain formation in relatively lesser time when compared to tolerant genotypes, denoting the fact that tolerant genotypes had less ovule abortion despite of moisture stress.

Seed weight reduction under drought stress might be a result of cytokine in reduction. In this condition less endosperm cells is produced in seeds (Bradford, 1994).



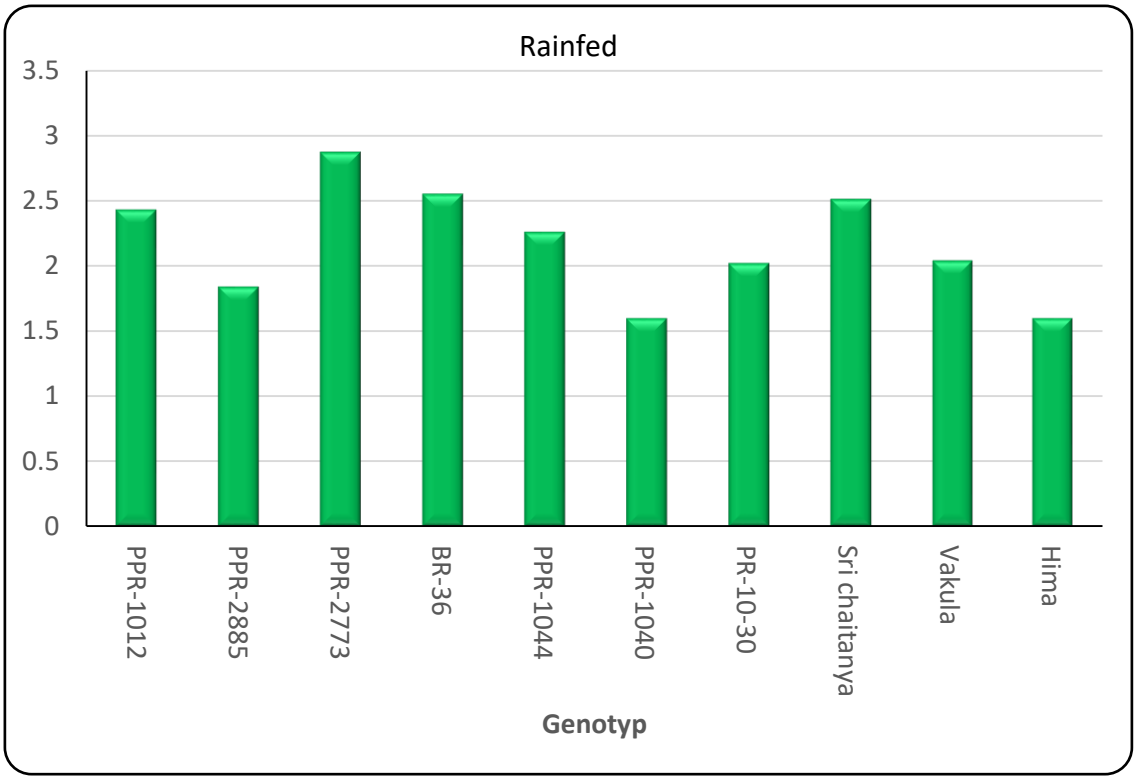


Fig. 4.17. Evaluation of ragi genotypes for 1000 grain weight under rainfed conditions

4.4.4 Grain Yield (kg ha^{-1})

Grain yield of ragi genotypes as affected by rainfed and irrigated treatments are presented in Table 4.16 and Fig. 4.18.

Significant differences were noticed between treatments, genotypes and their interactions. Similar differences between the moisture stress treatment and their interactions were reported in durum wheat varieties by Moaed Almeselmani *et al*. (2012).

Dey and Upadhyaya, (1996) suggested three different critical stages of growth–seedling vegetative and anthesis, which are highly affected by water stress and reduces the estimates of component characters finally grain yield.

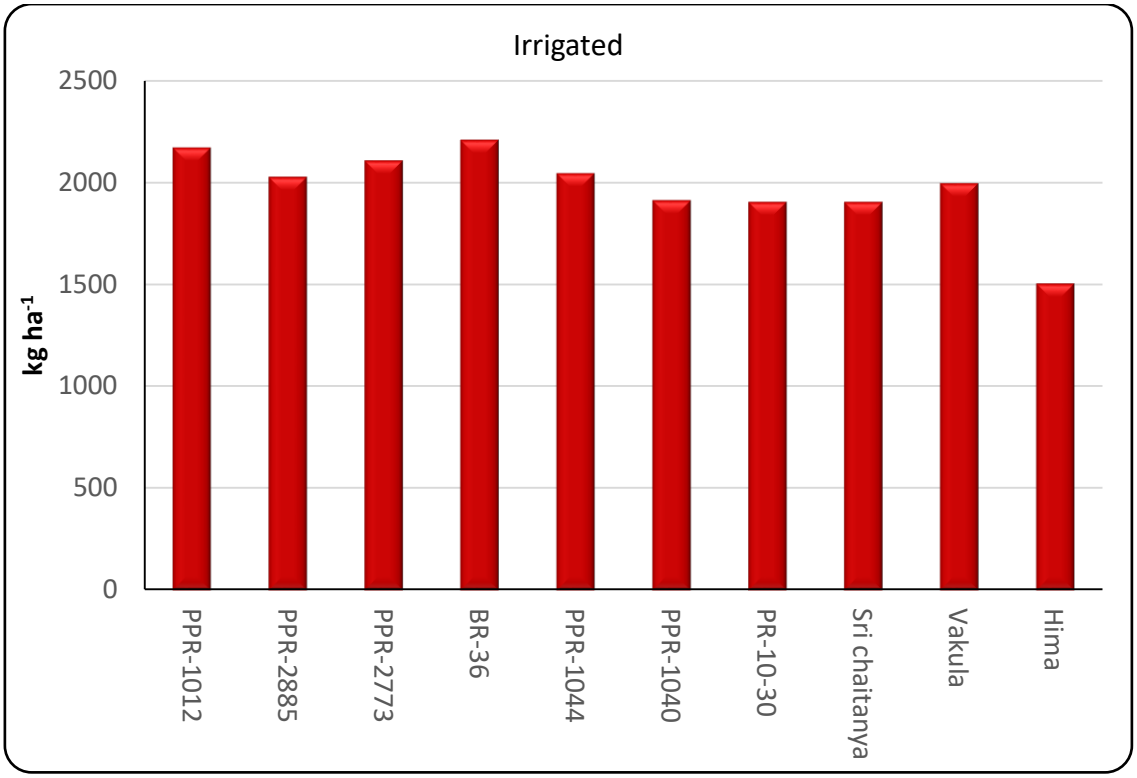
Among the genotypes BR-36 recorded significantly higher grain yield of 2115.39 kg ha^{-1}, followed by 1012 (2045.21 kg ha^{-1}) and PPR-2773 (2007.03 kg ha^{-1}) compared to other entries. These genotypes are proved to be high yielders under irrigated as well as drought conditions. However, the genotypes PR-10-30, Srichaitanya, Hima recorded poor yield under moisture stress conditions, despite of recording higher yields under irrigated conditions. Similar results of decrease in the grain yield due to moisture stress was reported in prosomillet (Seghatoleslami *et al*., 2008).

Mahalakshmi and Bidinger (1985) and Kumari (1988) also reported that drought stress in pearl millet decreased seed yield through reduction of seed number per ear and seed weight. Leila Radhouane (2013) reported that reduction in the grain yield of prosomillet under stress conditions is mainly due to reduced panicle number per m^2.

The present study evaluated three identified genotypes BR-36, PPR-1012 and PPR-2773 which possess high WUE, and other drought tolerance traits and grain yield. Hence these genotypes are suitable for rainfed conditions.

Table 4.16. Evaluation of ragi genotypes for grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index under rainfed conditions

Genotype	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	2170.33	1920.09	2045.21	5420.64	5224.77	5322.71	34.57	29.29	31.93
PPR-2885	2025.87	985.17	1855.52	5233.61	4725.67	4979.64	26.07	18.38	22.23
PPR-2773	2107.33	1406.72	2007.03	4844.09	4633.49	4877.85	29.83	29.47	29.65
BR-36	2207.33	1901.45	2054.39	5348.64	4911.60	4991.07	45.80	42.35	44.08
PPR-1044	2044.40	977.73	1861.07	4421.50	4039.64	4230.57	29.48	20.05	24.77
PPR-1040	1911.07	1688.87	1799.97	4623.22	4123.76	4373.49	28.58	25.01	26.80
PR-10-30	1903.67	899.97	1751.82	3946.12	3655.56	3800.84	29.77	18.64	24.21
Sri chaitanya	1903.67	1659.23	1781.45	4431.89	4256.97	4344.43	29.15	17.44	23.30
Vakula	1994.60	1704.13	1849.37	4731.00	4494.69	4612.85	30.14	24.57	27.36
Hima	1503.67	1085.13	1394.40	3712.76	3515.78	3614.27	19.70	20.38	20.04
Mean	**1977.19**	**1715.04**		4671.34	4388.67		30.309	24.558	
	T	**G**	**T x G**	**T**	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**8.1435**	**18.2995**	**25.7521**	**0.0243**	**0.0544**	**0.0769**	**1.97**	**4.41**	**6.24**
CD(P=0.005)	**23.3205**	**52.1461**	**73.764**	**0.0697**	**0.1558**	**0.220**	**5.65**	**12.63**	**17.86**



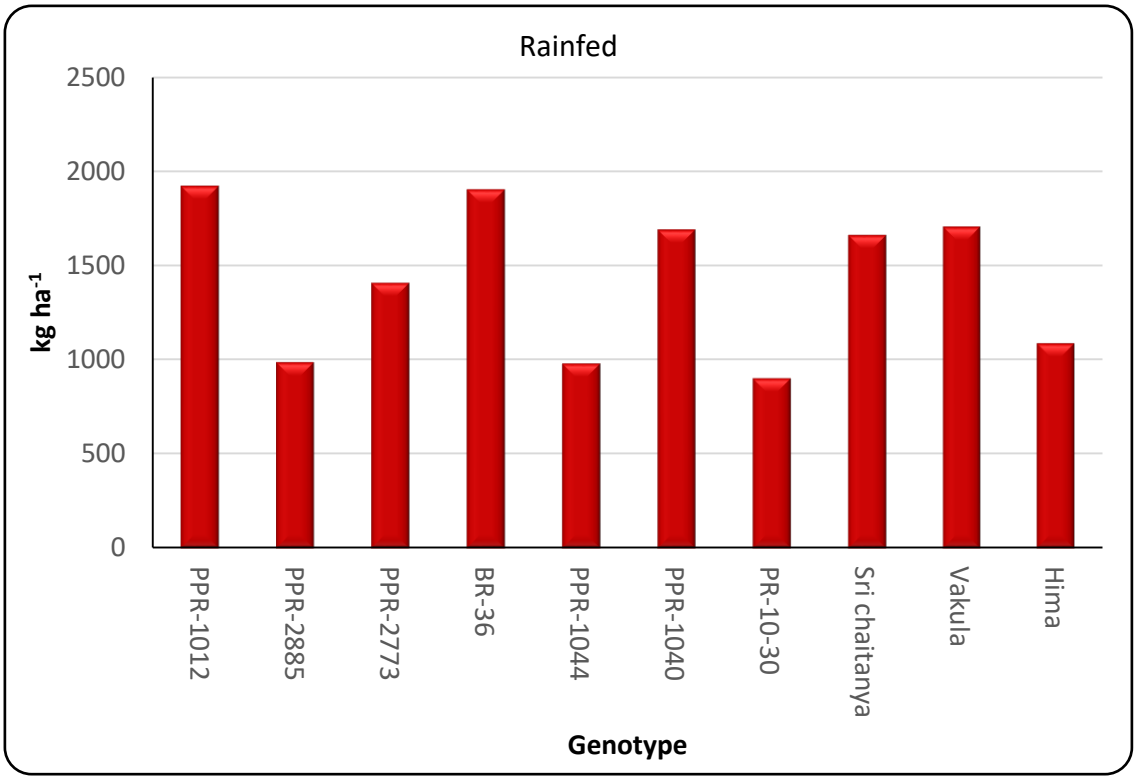


Fig. 4.18. Evaluation of ragi genotypes for grain yield (kg ha^{-1}) under rainfed conditions

4.4.5 Straw Yield (kg ha^{-1})

The harvested dry straw yields of ragi genotypes as influenced by irrigation and rainfed treatments are presented in Table 4.16 and Fig. 4.19.

Treatments, genotypes and their interactions were significantly varied for straw yields (kg ha^{-1}). Among the treatments, rainfed caused significant reduction (6.05%) in straw yield compared to irrigated control.

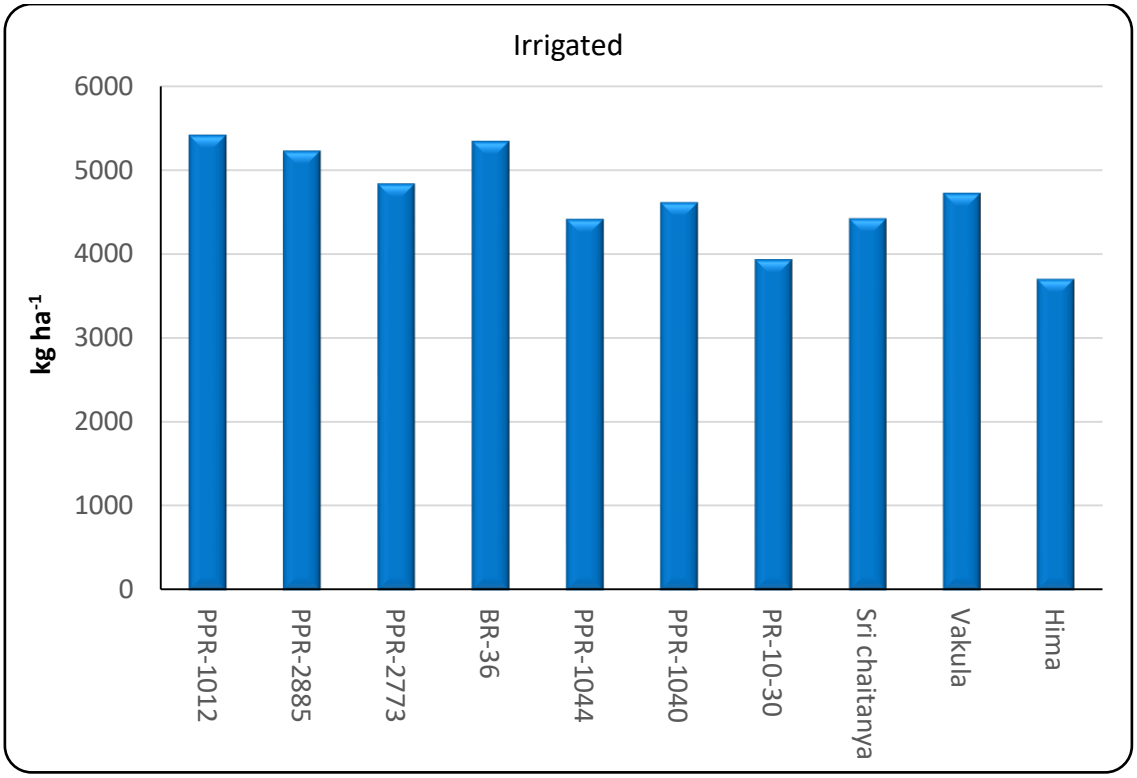
Among the genotypes tested, BR-36 (4991.07 kg ha^{-1}), PPR-1012 (5322.71 kg ha^{-1}), recorded significantly high mean straw yield followed by PPR-2885 (4979.64 kg ha^{-1}). The genotypes Hima (3614.27 kg ha^{-1}) recorded lowest straw yields. The other genotypes PPR-2773, PPR-1040, PPR-1044, PR-10-30 and vakula reported moderate straw yields. Finger millet straw is also a valuable livestock feed it makes good fodder and contain upto 61 per cent to total digestable nutrients (National Research Council, 1996; Updhyaya *et al.* 2007).

4.4.6 Harvest Index (%)

Harvest index of ragi genotypes as affected by rainfed and irrigated treatments are presented in Table 4.16 and Fig. 4.20.

Harvest index is one of the major component for higher grain yields. Significant differences were noticed between moisture stress treatments, genotypes and their interactions. Due to dry spell from 47-67 DAS mean harvest index was significantly decreased (18.97%) compared to irrigated control, which indicated that moisture stress affected partitioning of photosynthates. Murty (1992) reported that has shown an increased yield and biomass upto 250 kg N ha^{-1} with no change in the HI in case in rice.

Similar results were also reported by Mohapatra (1989) further varieties selected for high and low HI respectively at a given level of N. These results indicate the stability of HI over N levels in finger millet crop.



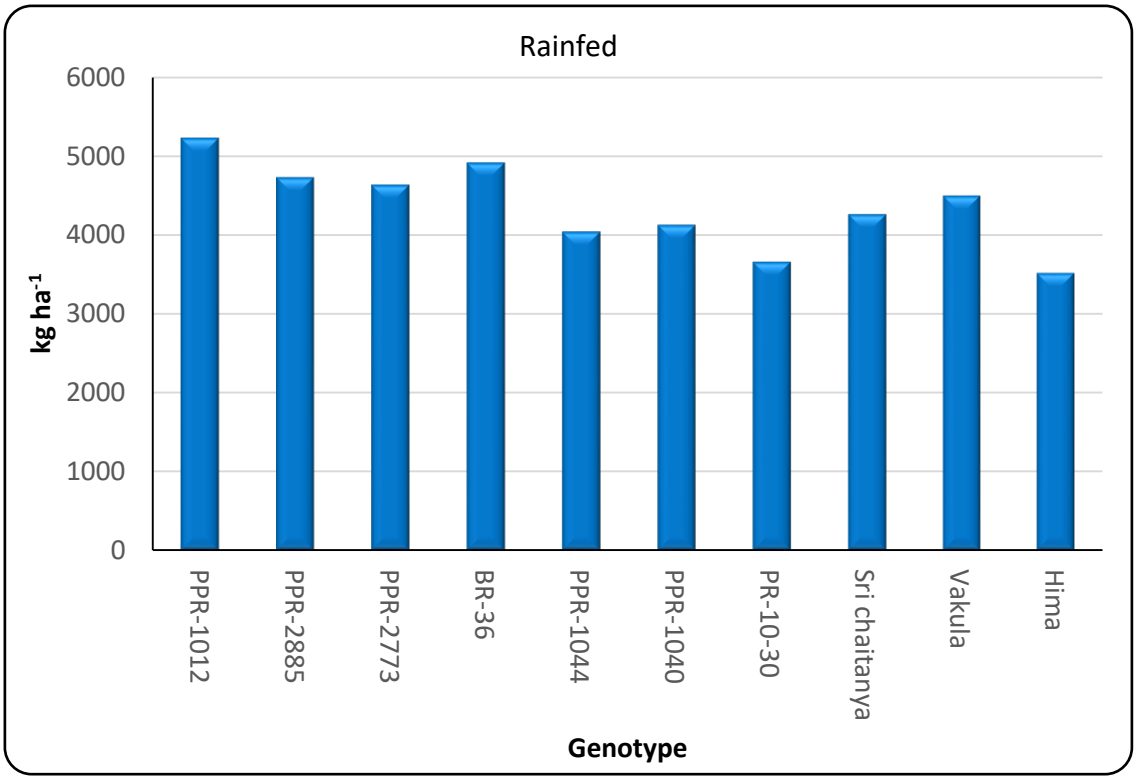
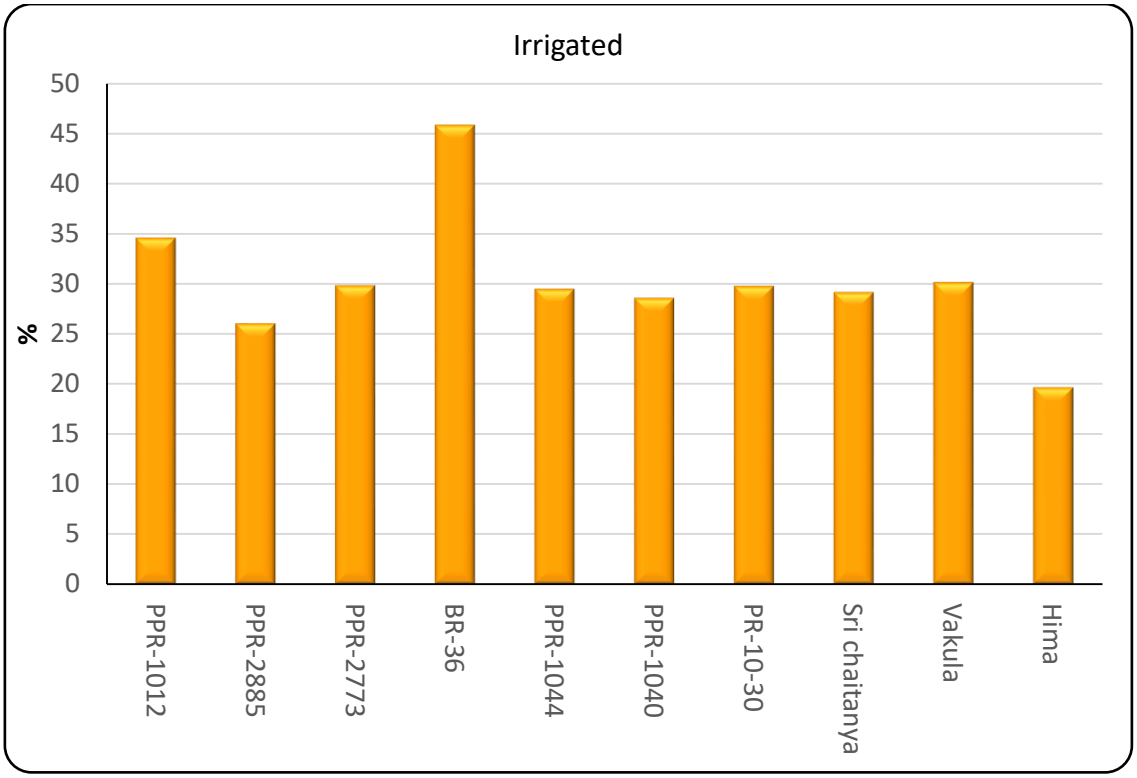


Fig. 4.19. Evaluation of ragi genotypes for straw yield (kg ha^{-1}) under rainfed conditions



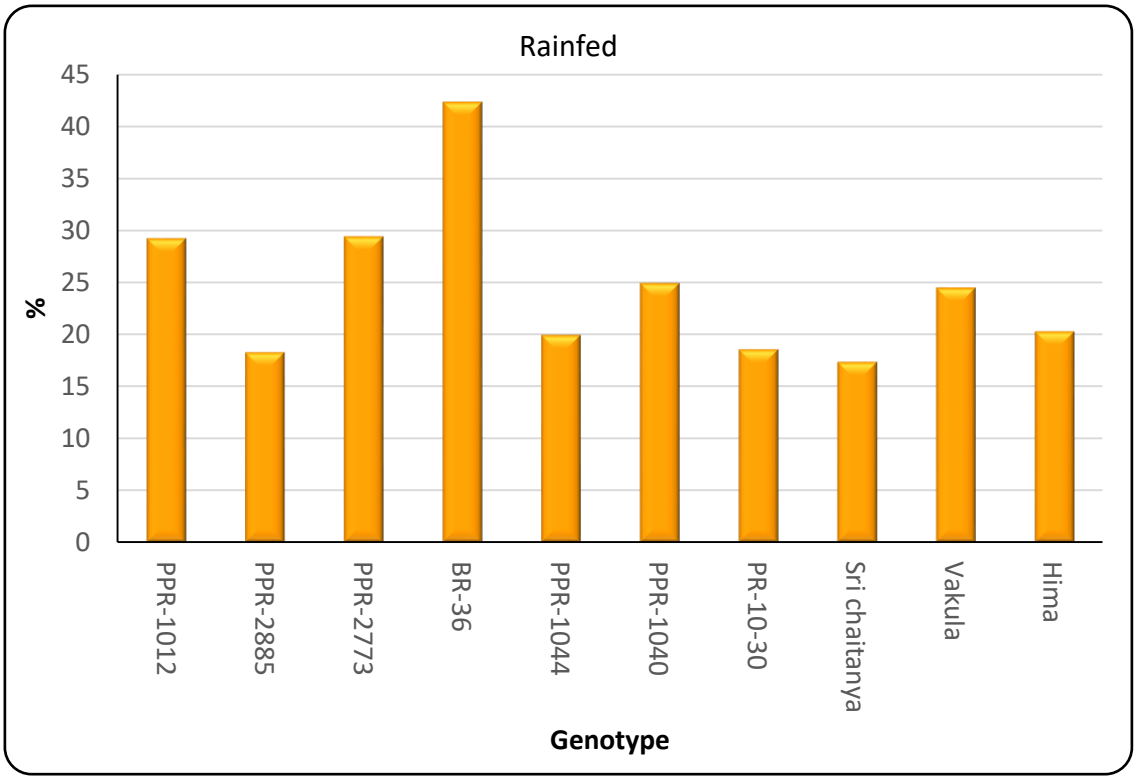


Fig. 4.20. Evaluation of ragi genotypes for harvest index under rainfed conditions

Similar results of reduction of harvest index under moisture stress conditions was reported (Seghatoleslami *et al*., 2008) in proso millet. Among the genotypes BR-36 recorded highest mean harvest index (44.07) followed by PPR-1012 (31.93) compared to other genotypes. PPR-1040, PPR-1044 PR-10-30, Srichaitanya and Vakula recorded moderate harvest index, whereas, Hima and PPR-2885 recorded lowest harvest index.

The higher harvest index of these genotypes represents an increased physiological capacity to mobilize photosynthates and translocate them efficiently to organs of economic value, i.e. grain yield as opined by Wallace *et al.* (1972).

4.5 QUALITY PARAMETERS

4.5.1 Protein Content (%)

Harvested grains of ragi genotypes were estimated for protein content and presented in Table 4.17.

Differences among treatments, genotypes and their interactions were non significant. Among the genotypes PPR-2773(7.35) recorded higher protein content compared to other genotypes. PPR-1040, PPR-1012, BR-36, PPR-1044 PR-10-30, Srichaitanya, Hima and Vakula recorded moderate harvest index, where as and PPR-1040 (6.79) recorded lowest protein content.

4.5.2 Calcium Content (mg 100 g^{-1})

Harvested grains of ragi genotypes were estimated by calcium content and presented in Table 4.17.

Singh and Raghuvanshni (2012) reported that the finger millet is a good source of nutrients especially of calcium, other minerals and fiber. The mineral composition of millet grains is highly variable. The genetic factors

Table 4.17. Evaluation of ragi genotypes for protein content (%) and calcium content (mg 100 g^{-1}) under rainfed conditions

Genotype	Protein (%)			Calcium content (mg 100 g^{-1})		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	7.16	7.06	**7.11**	276.8	272.9	**274.9**
PPR-2885	7.12	7.05	**7.09**	272.1	266.4	**269.3**
PPR-2773	7.42	7.28	**7.35**	288.1	274.9	**281.5**
BR-36	7.22	6.98	**7.10**	280.7	275.1	**277.9**
PPR-1044	7.01	7.04	**7.03**	268.6	260.7	**264.7**
PPR-1040	6.82	6.76	**6.79**	265.9	259.8	**262.9**
PR-10-30	6.95	6.89	**6.92**	268.3	260.4	**264.4**
Sri chaitanya	7.11	7.09	**7.10**	269.1	261.8	**265.5**
Vakula	7.14	7.13	**7.14**	274.5	272.5	**273.5**
Hima	7.33	7.24	**7.29**	276.5	269.3	**272.9**
Mean	**7.128**	**7.052**		**274.06**	**267.38**	
	T	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.2868**	**0.6413**	**0.907**	**14.205**	**31.765**	**44.922**
CD(P=0.005)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

and environmental conditions prevailing in growing regions affect the mineral content of these food grains.

Differences among treatments, genotypes and their interactions were non significant and only numerical differences were recorded.

Among the genotypes PPR-2773(281.5) recorded highest mean calcium content compared to other genotypes. PPR-1040, PPR-1012, BR-36, PPR-1044 PR-10-30, Sri chaitanya, Hima and Vakula recorded moderate harvest index, where as and PPR-1040 (262.9) recorded lowest calcium content.

4.5.3 Iron Content (mg 100 g^{-1})

Harvested grains of ragi genotypes were estimated for iron content and presented in Table 4.18.

Differences among treatments, genotypes and their interaction were non significant. Among the genotypes PPR-2773 (7.10) recorded higher iron content compared to other genotypes. PPR-1040, PPR-1012, BR-36, PPR-1044 PR-10-30, Sri chaitanya, Hima and Vakula recorded moderate harvest index, whereas and PPR-1040 (6.80) recorded lowest iron content.

4.5.4 Crude Fiber Content (%)

Harvested grains of ragi genotypes were estimated for fiber content and presented in Table 4.18.

Only numerical differences between treatments, genotypes interaction observed. Malleshi and Hadimani (1993) reported that finger millet can add substantial value to the diet in terms of protein and carbohydrates which is comparable to other cereals. In addition, it contributes vitamins, minerals and fiber as it is consumed whole in comparison to rice which is usually consumed after milling and polishing.

Table 4.18. Evaluation of ragi genotypes for iron content (mg 100 g^{-1}) and crude fiber content (%) under rainfed conditions

Genotype	Iron content (mg/100g)			Crude fibre (%)		
	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
PPR-1012	6.82	6.76	**6.79**	2.1	2.1	**2.10**
PPR-2885	6.89	6.78	**6.84**	2.2	2.1	**2.15**
PPR-2773	7.13	7.06	**7.10**	2.3	2.2	**2.25**
BR-36	6.95	6.88	**6.92**	2.2	2.1	**2.15**
PPR-1044	6.60	6.51	**6.56**	1.9	1.7	**1.80**
PPR-1040	6.94	6.86	**6.90**	1.7	1.5	**1.60**
PR-10-30	6.82	6.77	**6.80**	1.7	1.7	**1.70**
Sri chaitanya	6.75	6.72	**6.74**	1.9	1.4	**1.65**
Vakula	6.98	6.91	**6.95**	2.2	2.0	**2.10**
Hima	6.95	6.89	**6.92**	2.1	1.9	**2.00**
Mean	**6.888**	**6.814**		**2.03**	**1.87**	
	T	**G**	**T x G**	**T**	**G**	**T x G**
SE m±	**0.266**	**0.594**	**0.8412**	**0.134**	**0.299**	**0.423**
CD(P=0.005)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

Among the genotypes PPR-2773(2.25) recorded highest mean fiber content compared to other genotypes. PPR-1040, PPR-1012, BR-36, PPR-1044 PR-10-30, Sri chaitanya, Hima and Vakula recorded moderate harvest index, whereas and PPR-1040 (1.60) recorded lowest fiber content. Chandrasekhar *et al.* (1978) reported that high dietary fiber and phenolic content makes finger millet very beneficial for diabetic patients. Apart from this it also has low glycemic index (GI) that makes it an ideal snack to prevent late night food thirst and help to maintain blood sugar at a constant ratio.

Chapter ~ V

Summary & Conclusions

Chapter – V

SUMMARY AND CONCLUSIONS

Finger Millet, known locally as Ragi in the Indian sub-continent is mostly cultivated as a base crop in a mixed cropping. The crop is mostly cultivated in sub-marginal lands and limited moisture conditions. Much of the ragi crop is grown in *kharif* season and 70 per cent of *kharif* area is grown under rainfed situations .This is the prime reason for poor productivity of the ragi crop in India. Among drought mitigation technologies, development or identification of drought tolerant finger millet genotypes is a potential option and easily adopted by the resource poor farmers.

Hence, the present investigation was aimed at evaluating the relative performance of 10 (seven pre-release and three released) ragi genotypes for morphological, physiological characters, drought tolerant traits, yield and its attributes and grain quality parameters. These genotypes were evaluated in a field experiment, laid out in factorial randomized block design, replicated thrice with two main treatments i.e. adequately irrigated, rainfed and ten sub treatments (genotypes) in *Kharif*, 2015 at Agricultural Research Station (Millets), Perumallapalli, ANGRAU, Andhra Pradesh. During the experimental period there was long dry spell for 47 DAS to 67 DAS, which has coincided with panicle initiation and flowering stages.

The ragi genotypes differed in their response to rainfed and irrigated treatments in terms of morphological, physiological, yield and drought tolerant traits. All the morphological characters used for evaluating ragi genotypes under moisture stress conditions *viz.*, plant height, leaf area, total plant dry matter and its distribution among stem, leaf, root and grain significantly varied between moisture stress treatments and genotypes at and

after 60 DAS. However interaction effects were not significant through out the crop growth. Among the genotypes, the three pre- release genotypes viz., BR-36, PPR-1012 and PPR-2773 maintained high leaf area and dry matter accumulation under ranifed as well as irrigated conditions. Hima (Released variety) recorded low growth attributing characters and other genotypes PPR 2885, PPR-1044, PPR-1040, PR-10-30, Srichaitanya and Vakula recorded moderate values.

The two important green leaf growth parameters viz. leaf area index (LAI) and leaf area duration (LAD) which denotes light interception and current photosynthesis were affected in rainfed treatments compared to irrigated control. The genotypes, BR-36,PPR-1012 and PPR-2773 which maintained higher leaf area and dry matter also maintained higher LAI and green leaf area for longer periods under both irrigated and rainfed conditions.

Among the drought tolerant traits used to evaluate ragi genotypes, WUE traits *viz*., SLA, SCMR, and other drought tolerant traits viz., Chlorophyll stability Index, RWC, were reduced under rainfed conditions compared to irrigated control. Whereas root length, and leaf Proline contents were increased under rainfed conditions compared to irrigated control. The genotypes, BR-36, PPR-1012 and PPR-2773 maintained higher WUE traits i.e. moderate SLA and high SCMR values. These genotypes also recorded higher drought tolerant traits like Chlorophyll stability Index, RWC, root length, and leaf Proline compared to other genotypes, which denotes efficiency in performing under drought condition. Released variety Hima recorded lowest drought tolerant characters, denoting its susceptibility under drought conditions. Other genotypes showed moderate tolerance to drought tolerance.

Yield components *viz.*, number of tillers plant^{-1}, number of fingers plant^{-1}, 1000 grain weight, straw yield as well as grain yields and Harvest Index were significantly reduced due to moisture stress compared to control. The genotypic differences and their interaction effects were also showed significant. BR-36, PPR-1012 and PPR-2773 recorded higher yield and its components both under irrigated and imposed moisture stress conditions.

Grain quality attributes recorded after harvest viz., Protein percent, Calcium content, Iron content and crude fiber contents were varied numerically only, which denotes the dry spell occurred during experimentation did not influence grain quality characters.

Conclusions

- Dry spell (Rainfed condition) at critical stages viz., panicle initiation and flowering stages in ragi crop affected all growth and Physiological efficiency parameters.
- Among the genotypes, the three pre release genotypes viz., BR-36, PPR-1012 and PPR-2773 are superior in terms of physiological efficiency, drought tolerance, yield and yield components under ranifed as well as irrigated conditions. These can be further tested under minikit trails to recommend for rainfed areas.
- Besides, the same entries one potential donors for crop, improvement for drought tolerance/.
- Hima (Released variety) recorded low performance and it will not fit in rainfed areas.
- PPR 2885, PPR-1044, PPR-1040, PR-10-30, Srichaitanya and Vakula recorded moderate drought tolerance combining with good yielding abilities.

- Grain quality attributes viz., Protein percent, Calcium content, Iron content and crude fiber contents were varied numerically only between treatments and genotypes.
- Wide genotypic variability among ragi genotypes were observed for growth, drought tolerance, yield and its attributes.
- In ragi, moisture stress tolerance parameters viz., SCMR, Chlorophyll stability index, Relative water content, leaf proline content are reliable simple and repeatable traits and mapping populations for screening genotypes for drought tolerance.

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