Research Article

Biochemical Characterization of Barnyard Millet and Foxtail Millet under Rainfed Condition

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Abstract

Barnyard millet and foxtail millet are the oldest domesticated millets and it is a staple cereal in areas where climatic and edaphic conditions are unsuitable for Cultivation. It is suited to conditions of low and moderate rainfall area due to early maturity period. The low yield in these millets are generally attributed to physiological and biochemical factors. All the factors influencing growth and development of crop plants are to be integrated at an optimum level for maximum production potential. Understanding the biochemical changes in crops plants at different stages helps to understand their adaptations to extreme climate changes and crop characteristics. In this study, we assessed the biochemical constituents such as soluble protein, proline, nitrate reductase and catalase activity at five different growth stages (vegetative, flowering, grain development, grain maturity and harvest) of barnyard millet and foxtail millet. The proline accumulation was highest at grain development stage in all the small millets (1.43 to 2.02 mg/g) and was the maximum in barnyard millet. Soluble protein and nitrate reductase activity were the maximum in foxtail millet; both increased from flowering to grain development stages and decreased in later stages. Barnyard millet had the highest catalase activity in all five growth stages, followed by foxtail millet across the growth stages.

Keywords: Proline, Soluble protein, nitrate reductase, catalase, growth stages, barnyard millet, foxtail millet

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Introduction

Small millets, such as barnyard millet and foxtail millets are considered as one of the important nutri-rich climate-smart crops [1]. These small millets are adapted to varied agro-climatic regions, and their use as food, feed and fodder make them important for crop productivity and food security [2]. Both these small millets are suited to conditions of extreme weather condition. Besides India, these small millets are also grown in Japan, USA and other African and East Asian countries. In India, the cultivation of small millets is confined to Andhra Pradesh, Karnataka, and Tamil Nadu. In India, these small millets are cultivated in limited area of 0.4 m ha and occupy about 3.2 lakhs ha with a production of 1.15 lakhs tons, with a productivity of 380 kg/ha (averaged between 2005-2009). Potential yields of up to 2 tons in these millets were reported (http://www.aicrpsm.res.in/Reports.html), indicating a large yield gaps to enhance productivity following improved crop management practices and cultivation high yielding cultivars. Assessing the change in biochemical constituents in foxtail millet and barnyard millet at different growth stages and the relationship with yield would help in understanding the basis of varietal differences in terms of crop productivity. This study aims to assess the biochemical constituents such as soluble protein, nitrate reductase, proline and catalase at different growth stages of five small millets.

Materials and methods

The experiment was conducted at Eastern Block Farm of Tamil Nadu Agricultural University, Coimbatore situated at 11Nº and 77Eº longitude with at an altitude of 426.7 m above mean sea level. This study included two cultivars each of barnyard millet (CO 1 and CO2) and three cultivars each of foxtail millet (CO 5, CO6, CO7). Together, 5 cultivars of two small millets were planted following randomized complete block design with three replications. The experiment received NPK in the form of urea, single super phosphate and muriate of potash, respectively at the rate of 44: 22: 15 kg/ha. Full dose of P was applied as basal, whereas, N was applied in two splits, one as basal and another at 30 days after sowing (DAS). Potassium in the form of Muriate of potash was applied at 20^{th} and 40^{th}DAS.

Biochemical constituents such as soluble protein, nitrate reductase, proline and catalase activity were recorded at five different crop growth stages: vegetative, flowering, grain development, grain maturation and harvest. Soluble protein content was estimated from the leaf samples following the method of Lowry *et al.* (1951) [3] and expressed as mg g^{-1} fresh weight. Nitrate reductase activity was estimated by following the method of Nicholas *et al*. (1976) [4]

and the enzyme activity was expressed as µmol NO_2 g^{-1} h^{-1}. Proline accumulation in the leaf was estimated by the method of Bates *et al.* (1973) [5]. The proline content was expressed in mg g^{-1} fresh weight. Catalase activity was determined according to Teranishi *et al.* (1974) [6] and expressed as µg of H_2O_2 reduced min^{-1} g^{-1} fresh weight.

The data collected on the different parameters were statistically analysed by the 'F' test for significance as suggested by Gomez and Gomez (2010) [7]. The critical difference (CD) was computed at 5% probability.

Results and Discussion

Small millets such as foxtail millet and barnyard millet are highly nutritious and have several health perspectives. Small millets also climate resilient crops, and they are less affected by insect pests and diseases and abiotic stress. Small millets cultivation and consumption has been a drastic declined in production mainly due to limited productivity, high drudgery involved in their processing and negative perceptions of small millets as a food for the poor.

In this study, we assessed the biochemical constituents such as soluble protein, proline, nitrate reductase and catalase at five different growth stages (vegetative, flowering, grain development, grain maturity and harvest) and two small millets (foxtail millet and barnyard millet). Understanding the biochemical changes in crops plants at different stages helps to understand their adaptations and crop characteristics.

Soluble protein content was the highest in foxtail millet in vegetative (14.70), flowering (160.90), grain development (18.43) and grain maturation (12.90) stages and was second largest at harvest (7.40) stage, and significantly different at all stages (**Table 1**). Among five crop growth stages, soluble protein content was the highest at grain development stage (18.43 in foxtail millet) and the lowest at harvest (6.25 in barnyard millet) stage in all five these different varieties small millets. In this study, soluble protein was the maximum in foxtail millet in first four growth stages, and was the second highest at harvest stage, as compared to other barnyard millet varieties. It reached the maximum at grain developmental stage and reduced at maturity. There were reports that RuBP-case enzyme forms nearly 80% of the soluble proteins in leaves of many plants [8]. Diethelm and Shibles (1989) [9] opined that the RUBISCO content per unit leaf area was positively correlated with that of soluble protein content of the leaf. Soluble protein, world’s most abundant protein containing the enzyme RUBISCO, is involved in CO_2 assimilation; therefore, the reduction in soluble protein might have a direct adverse effect on photosynthesis.

Table 1 Soluble protein (mg g^{-1}) content of small millets at different growth stages

Crop	Stages				
	Vegetative	**Flowering**	**Grain development**	**Grain maturation**	**Harvest**
Barnyard millet					
CO 1	8.3	10.2	13.1	11.5	5.7
CO 2	9.5	12.6	16.4	12.4	6.8
Foxtail millet					
CO 5	13.4	17.5	19.9	13.6	6.5
CO 6	14.2	15.7	16.6	12.3	6.9
CO 7	16.5	17.5	18.8	12.8	8.8
Mean	12.38	14.70	16.96	12.52	6.94
SED	0.135	0.241	0.291	0.132	0.649
CD (0.05)	0.294	0.526	0.527	0.289	0.141

Nitrate reductase was the highest at grain maturation stage (72.35 in foxtail millet) and harvest (34.35 in foxtail millet to 39.61 in barnyard millet) stages. Nitrate reductase was the maximum at flowering, grain development and grain maturation stages in foxtail millet, while in barnyard millet at flowering and harvest stage (**Table 2**). We have observed the maximum nitrate reductase (NR) activity at flowering, grain development and grain maturity stages in foxtail millet, while it was the maximum at harvest stage in barnyard millet. Nitrate reductase plays a pivotal role in the plant nitrogen supplement for growth, development and productivity, in the initiation of nitrogen metabolism and the level of protein synthesis, and NR mediates conversion of nitrate to nitrite.

In this study, the proline accumulation was highest at grain development stage in all the small millets (1.43 to 2.02 mg/g) and was the maximum in barnyard millet, followed foxtail millet at grain development stage (**Table 3**). This shows that the barnyard millet cultivars able to tolerate under stress compared to foxtail millets studies, and proline accumulation is the highest at grain developmental stage in all crops. Proline content was the highest at grain developmental stage and reduced significantly afterwards in all these five small millet varieties. A maximum proline content of 2.02 was found at grain development stage in barnyard millet. It is well described that under stress conditions many plant species accumulate proline as an adaptive response to adverse conditions and plays important role in plant growth and development [9]. Catalase activity was highest in barnyard millet at all five growth stages (**Table 4**), followed by foxtail millet. Catalase is a heme-containing enzyme and it's found in all aerobic eukaryotes and is important in the removal of hydrogen peroxide generated in peroxisomes by oxidases involved β-oxidation of fatty acids, the glyoxylate cycle (photorespiration) and purine catabolism.

Table 2 Nitrate reductase activity (µg NO_2 g^{-1} hr^{-1}) of small millets at different growth stages

Crop	**Stages**				
	Vegetative	**Flowering**	**Grain development**	**Grain maturation**	**Harvest**
Barnyard millet					
CO 1	34.05	43.37	51.47	54.53	38.11
CO 2	38.65	48.32	66.53	67.42	41.11
Foxtail millet					
CO 5	31.26	46.79	61.11	67.21	35.32
CO 6	35.95	47.68	64.11	71.74	31.00
CO 7	36.47	48.00	68.16	78.11	36.74
Mean	35.27	46.83	62.27	67.80	36.45
SED	0.465	0.657	1.008	0.887	0.603
CD (0.05)	1.014	1.933	2.196	1.933	1.315

Table 3 Proline Content (mg g^{-1}) of small millets at different growth stages

Crop	**Stages**				
	Vegetative	**Flowering**	**Grain development**	**Grain maturation**	**Harvest**
Barnyard millet					
CO 1	1.21	1.28	1.96	1.36	1.05
CO 2	1.24	1.29	2.08	1.45	1.09
Foxtail millet					
CO 5	1.22	1.30	1.59	1.32	1.01
CO 6	1.25	1.31	1.78	1.35	1.02
CO 7	1.26	1.32	1.56	1.42	1.03
Mean	1.22	1.30	1.59	1.32	1.01
SED	0.011	0.018	0.028	0.013	0.016
CD (0.05)	0.022	0.041	0.062	0.029	0.035

Table 4 Catalase activity of small millets at different growth stages

Crop	**Stages**				
	Vegetative	**Flowering**	**Grain development**	**Grain maturation**	**Harvest**
Barnyard millet					
CO 1	7.1	10.2	8.89	9.24	11.01
CO 2	6.8	9.34	9.32	8.64	10.87
Foxtail millet					
CO 5	6.5	9.67	8.97	8.73	9.22
CO 6	5.8	8.60	8.21	7.78	8.87
CO 7	4.7	9.23	7.24	4.21	6.25
Mean	4.7	8.55	7.36	6.55	7.87
SED	0.056	0.131	0.100	0.084	0.105
CD (0.05)	0.124	0.285	0.218	0.184	0.229

Conclusion

The biochemical traits follows similar pattern at different growth stages in foxtail millet and barnyard millet were investigated. However concentration varies with crops, suggesting differential response of crops with respect to their adaptation to withstand extreme environmental condition.

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