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Evaluating changes in total sugars, fructans and alcohol insoluble solids in onion (*Allium cepa* L.) genotypes during ambient storage conditions

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Abstract
The present investigations were carried out at Vegetable Research Farm and Biochemistry Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana with an aim to study the changes in total sugars, fructans and alcohol insoluble solids contents under ambient storage conditions in thirty genotypes of onion (*Allium cepa* L.). The experiment was designed as a domestic model of India, in which the onions are mainly stored at ambient temperature. The samples were randomly collected during the sampling period from the month of May to September at monthly intervals to analyse the contents of total soluble sugars, fructans, alcohol insoluble solids. It was found that during the storage period, there was a significant reduction in the amount of total soluble sugars and fructans while the content of alcohol insoluble solids significantly increased in all varieties. In onion bulbs, highest amount of total sugars, fructans and alcohol insoluble solids, were found in variety D-96-B, D-305-B, GSY 10-2, respectively. The interaction between varieties and the time period as well as within the thirty varieties was statistically significant.

Keywords: Alcohol insoluble solids, fructans, onion, sugars, storage

Introduction
Onion (*Allium cepa* L.) is an herbaceous biennial plant having edible bulbs. The onion is probably native to South Western Asia but is now grown throughout the world, chiefly in the temperate zones. India is the second largest producer of onion in the world next to China. In India, the area under onion cultivation is 1285 thousand hectares with an annual production of 232 lakh tonnes (Anonymous 2018) [3]. In Punjab, onion covers an area of 8.84 thousand hectares with a production of 202 thousand tonnes (Anonymous 2017) [2]. Onion is a cool season crop, hardy to frost but less sensitive to heat. In India, onion is grown in two seasons i.e. Rabi and Kharif. Rabi onion is planted during the month of October-November and harvested in May-June (Futane *et al.* 2018) [13]. According to USDA National Nutrient Database for Standard Reference Release 2018, 100g of onion contains water (89.11 g), energy (40 Kcal), protein (1.10 g), total lipid (0.10 g), carbohydrates (9.34 g), fibre (1.7 g), sugars (4.24 g), vitamin C (7.4 mg), thiamine (0.046 mg), riboflavin (0.027 mg), niacin (0.116 mg) and pyridoxin (0.120 mg) (Anonymous 2018) [1]. Onion bulbs are mainly used as storage parts. After harvesting, onion bulbs are cured and stored for about four to five months or longer according to the storage conditions.

A number of biochemical and physiological changes are observed during the storage like change in texture, carbohydrate content, flavor related compounds etc. Carbohydrates in onion bulbs are composed mainly of glucose, fructose, sucrose, and fructans, and sugar composition during storage is strongly associated with the transition of these components from dormancy to sprouting period. Water soluble carbohydrates in onion bulbs include fructose, glucose and sucrose and a series of oligosaccharides called fructans (Darbyshire and Henry 1978) [9]. Fructans constitute 60 to 80 per cent of the total dry weight of onion bulb as found by Rutherford and Whittle (1982) [25]. Fructo-oligosaccharides, especially those with higher degree of polymerization, are the main energy reserves in onion bulbs that provide the catabolic substrates for shoot growth during sprouting through their hydrolysis (Pak *et al.* 1995) [22]. Because of various metabolic activities occurring during the storage of onion, the variation of sugar contents is observed (Rutherford and Whittle 1982 [25]; Hurst *et al.* 1985 [16]; Benkeblia *et al.* 2002 [6]; Benkeblia and Varoquaux 2003) [5].

However, to the best of our knowledge the fructans and alcohol insoluble solids, under the ambient storage conditions in these genotypes grown under Punjab conditions have not been not reported yet. Therefore, the present investigations were undertaken to study the changes in these biochemical parameters in thirty onion genotypes during storage at ambient temperature.

Materials and methods

The experiment was conducted at Vegetable Research Farm and Biochemistry laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India. Seeds of thirty genotypes of onion were grown in nursery and transplanted after 60 days of sowing. Bulbs were harvested at maturity, cured in field, transferred to the laboratory and stored in net baskets with proper aeration at ambient temperature. The biochemical parameters were estimated on first day after harvesting (presented as May) and then at monthly intervals till 4 months (presented as June, July, Aug and Sept) shown as 0-4 intervals. The onion bulbs were randomly selected and processed for the further estimation. For the present study the analytical grade chemicals i.e. ethanol, lead acetate, sodium oxalate, phenol, sulphuric acid, resorcinol, sodium hydroxide was used. Total sugars were estimated by the method suggested by Dubios *et al* (1956) [11]. In this method, the dried samples were extracted by refluxed it with ethanol and estimated with the addition of 5% phenol and conc. sulphuric acid at absorbance of 490nm. Fructans were estimated by the method suggested by Mcrary and Slattery (1945) [20]. In this, the extracted samples were estimated with the addition of 0.1% resorcinol solution (prepared in 95% ethanol) and 30% hydrochloric acid at the absorbance of 540 nm. Alcohol Insoluble Solids were determined by the method given by Moyer and Holgate (1948) [21]. The results presented are mean ± standard deviations for three replications. Two-way analysis between genotypes and time intervals was carried out by using two-way analysis of variance (ANOVA) and Student's t-test.

Results and discussion

Total Sugars: The data on the effect of storage on total sugars is presented in Figure 1. The significant change in total sugars with respect to storage period was observed. In the present study, the total sugars were found in the range of 40.60–792.07 mg g^{-1} DW during different stages and in different varieties. The average total sugars content in months May, June, July, August & September were 581.04, 465.79, 343.78, 259.76 & 102.24 mg g^{-1} DW respectively. The total sugars content decreased during the storage period. The maximum total sugars content was observed in May and minimum in September. The interactions between the varieties and the time intervals were observed statistically significant. In case of total sugars content, the best observed variety was D-96-B having mean value of all the months as 472.92 mg g^{-1} DW (maximum) & least observed variety was Punjab Selection having mean value 196.49 mg g^{-1}DW (minimum). The maximum varietal means were observed in the range of 300–400 mg g^{-1} DW.

Salamal *et al.* (1990) [26]. reported that the sugar level in outer and inner layers of the onion was 518 and 467 mg g^{-1} DW. Gorin and Borcsok (1980) [15] reported that onions stored for a long time had a reduced degree of 'freshness' with asimultaneous decrease in sugar content. Similar studies by Salamal *et al.* (1990) [26] have shown that total sugars reduced by increase in storage duration. Variation in the sugar content of bulbs during post-storage deterioration is characterized by a continuous decrease until the 10th week of storage (Sharma *et al.* 2014) [27]. The changes in dry weight concentrations of fructans, simple sugars and flavonols are consistent with those previously reported (Chope *et al.* 2006 [7], 2007 [8], Downes *et al* 2010) [10] and consistent between storage years despite the differences in the degree of fall-down at harvest. Changes in sugars in stored onion bulbs are well reported and have been reviewed by Chope *et al.* 2007 [8]. Benkeblia *et al.* (2002) [6] found that the pattern of changes in total soluble sugar content of 'Rouge Amposta' onion bulbs was similar at 4, 10 and 20 °C, suggesting that the catabolism of carbohydrates is more dependent on physiological stage than temperature. Carbohydrate content is significantly decreased during storage, mostly due to increased respiration, which consequently results in higher nitrogen and protein contents in the dry matter (Petropoulos *et al.* 2016) [23]. Soluble sugars are required to provide energy for sprout growth, so the concentration of soluble sugars decreases when sprouting occurs. The reason for the decrease in sugars level in onions is not very clear; it may be due to ageing.

Fructans/inulin: In the present study the fructans were found in the range of 0.88–61.24 mg $100g^{-1}$ FW in overall time stages and in varieties. The average fructans content in months May, June, July, August & September were 32.54, 22.99, 17.25, 10.33 & 5.58 mg $100g^{-1}$ FW respectively (Figure 2). The fructans content decreased during the storage. The maximum fructans content was observed in May and minimum in September. The interactions within the varieties and within the time intervals were observed statistically significant. In case of fructans content the best observed variety as D-305-B having mean value of all the months was 30.51 mg $100g^{-1}$ FW (maximum) while a minimum value was observed in variety REC-1428 having mean value 5.23 mg $100g^{-1}$ FW (minimum). The maximum varietal means were observed in the range of 15-20 mg $100g^{-1}$ FW, followed by 20-25 mg $100g^{-1}$ FW.

Fructans play the role of reserve carbohydrates that are synthesized from sucrose and fructose, accumulate in scales during bulbing and are consumed during the sprout development and re-growth phases (Pak *et al.* 1995 [22], Benkeblia *et al.* 2005) [4]. Suzuki and Cutliffe (1989) [28] reported the decrease in fructans content by storage compared with the fresh one. The conversion of fructan into sugars is one of the most important biochemical changes that occur during storage. Much of the carbohydrate metabolism during storage involves both partial and complete hydrolysis of the fructans (Suzuki and Cutliffe 1989) [28]. Sucrose and fructo-oligosaccharide hydrolyse by metabolizing enzymes seems to act as a biochemical signal for sprouting which increases the levels of fructose due to fructans hydrolysis (Benkeblia *et al.* 2005) [4], Rutherford and Whittle 1982 [25], Jaime *et al.* 2001 [17],

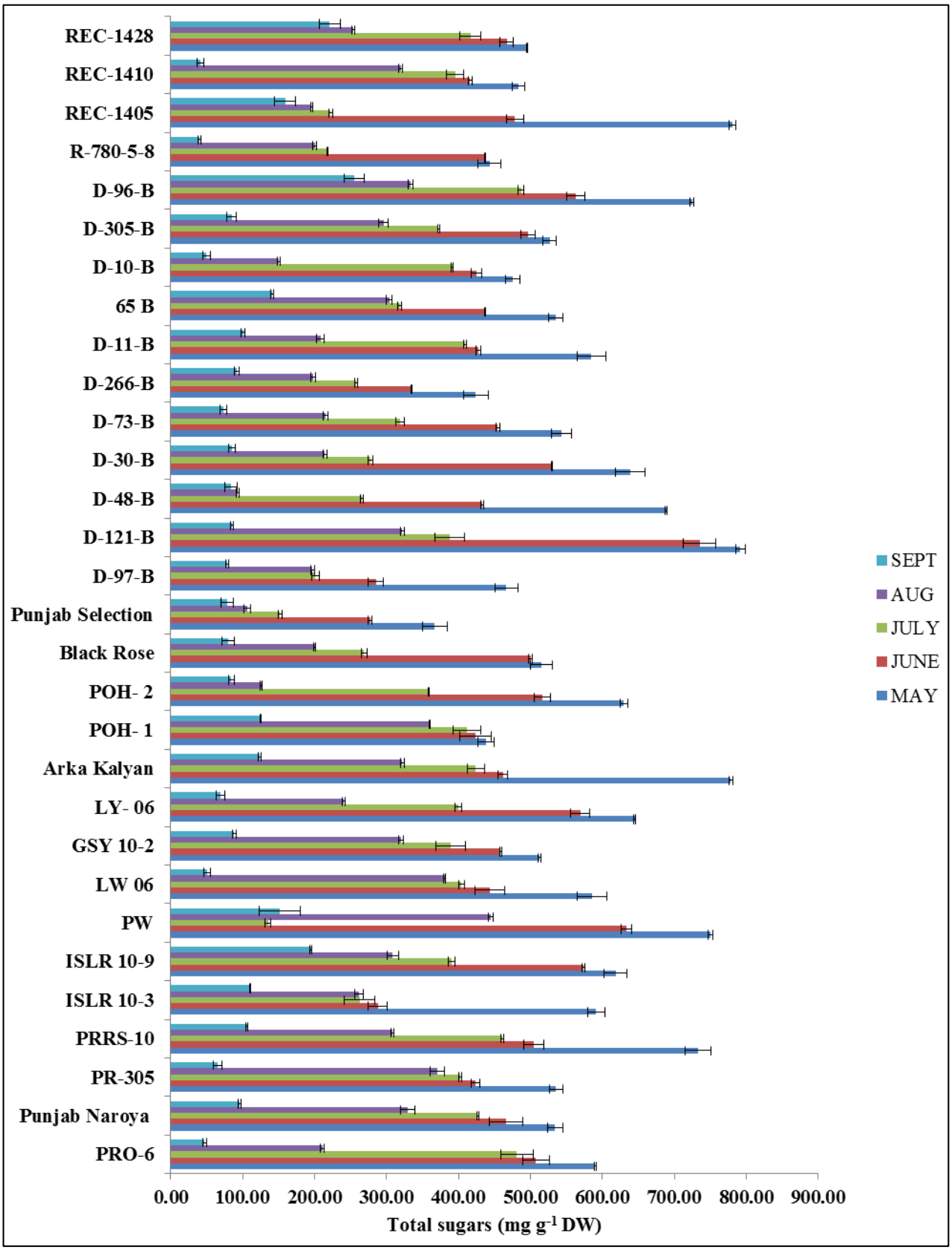

Fig 1: Total sugars content (mg g^{-1} DW) in thirty varieties of onion (*Allium cepa* L.) at different time intervals

Yasin and Bufler 2007) [31]. With the storage the nutritive value of the onion may reduce due to the decrease in fructans content (Suzuki and Cutliffe 1989) [28]. Fructans represent a major carbohydrate reserve in most onion bulbs, and, in general, are enzymatically hydrolysed to fructose during the storage period, accounting for a concomitant increase in fructose concentration (Hurst *et al.* 1985) [16].

Alcohol insoluble solids (AIS): In the present study, the alcohol insoluble solids content was found in the range of 226.67–740.00 mg g^{-1} DW in overall time stages and in varieties. The average AIS content in months of May, June, July, August & September were 342.33, 401.11, 462.22, 523.22 & 594.66 mg g^{-1} DW respectively (Figure 3). The alcohol insoluble solids content increased during storage. The maximum AIS content was observed in September and

minimum in May. The interactions between and within the varieties and the months were observed significant. According to the frequency distribution histogram it was observed that in the month of May, June, July, Aug, Sept the maximum number of 16, 13, 15, 12, 12 respectively genotypes were shown the AIS content ranged from 300-400, 400-500, 400-500, 500-600, 600-700 mg g^{-1} DW respectively. Kukanoor and Chavan (2010) [18] reported that the decrease in the total soluble solids irrespective of the treatment. The increase in alcohol insoluble solids may be due to the conversion of polysaccharides into simple sugars. Apart from controlled atmospheres, modified atmospheres could also be implemented for onion storage as soon as oxygen concentration is above a minimum threshold, since storage under low oxygen concentration (0.5% of O_2) resulted in lower total soluble solids due to reduced breakdown of fructans, which have a negative effect on flavor compared with higher oxygen concentration (Praeger *et al.* 2003 [24], Ernst *et al.* 2003) [12].

Conclusion

From the present studies it was concluded that, during the storage period of onion at ambient temperature, the total soluble sugars and fructans contents decreased whereas, alcohol insoluble solids content was increased and the interaction between the varieties and time intervals were found to be statistically significant.

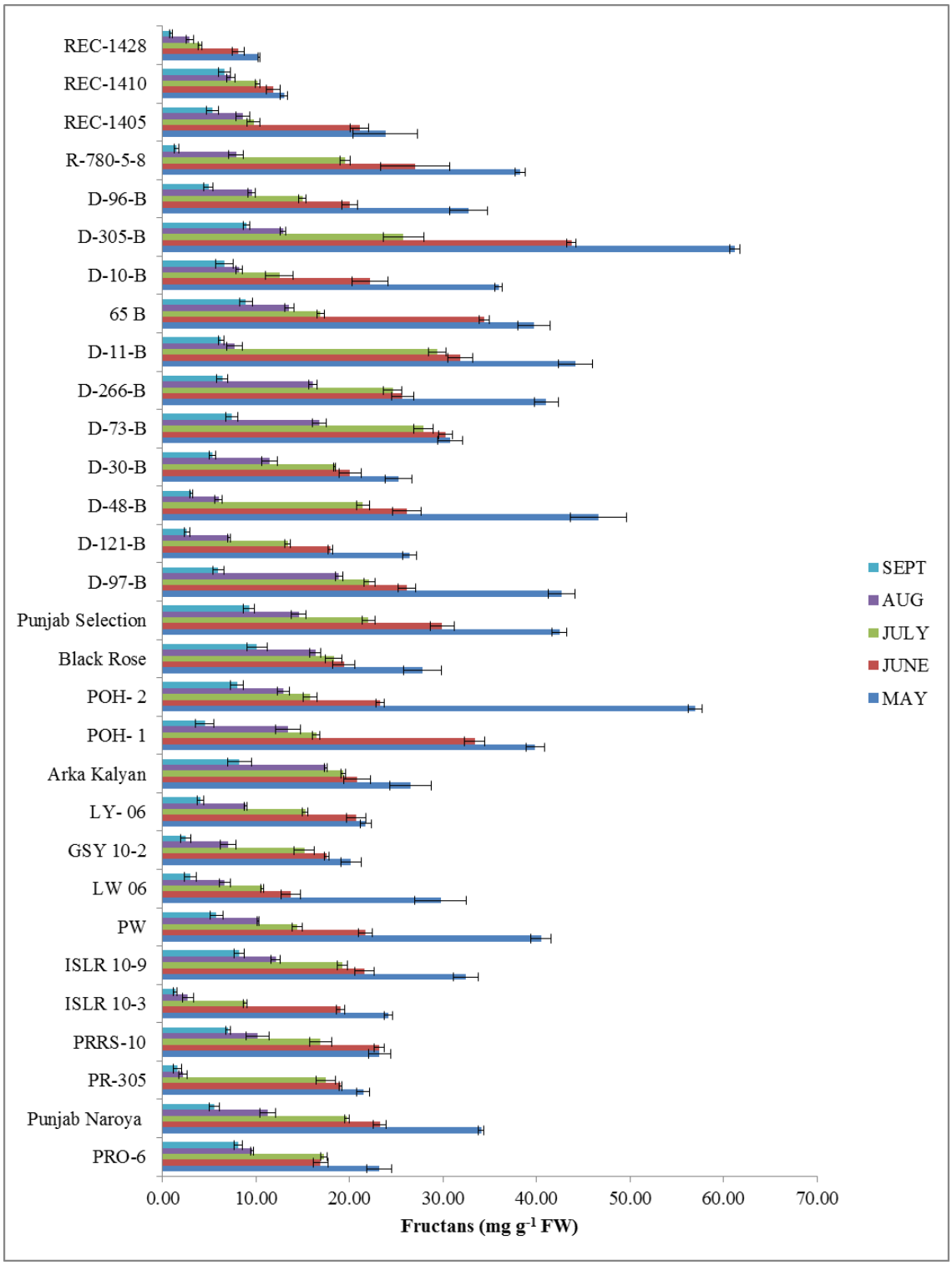

Fig 2: Fructans content (mg 100g^{-1} FW) in thirty varieties of onion (*Allium cepa* L.*)* at different time intervals

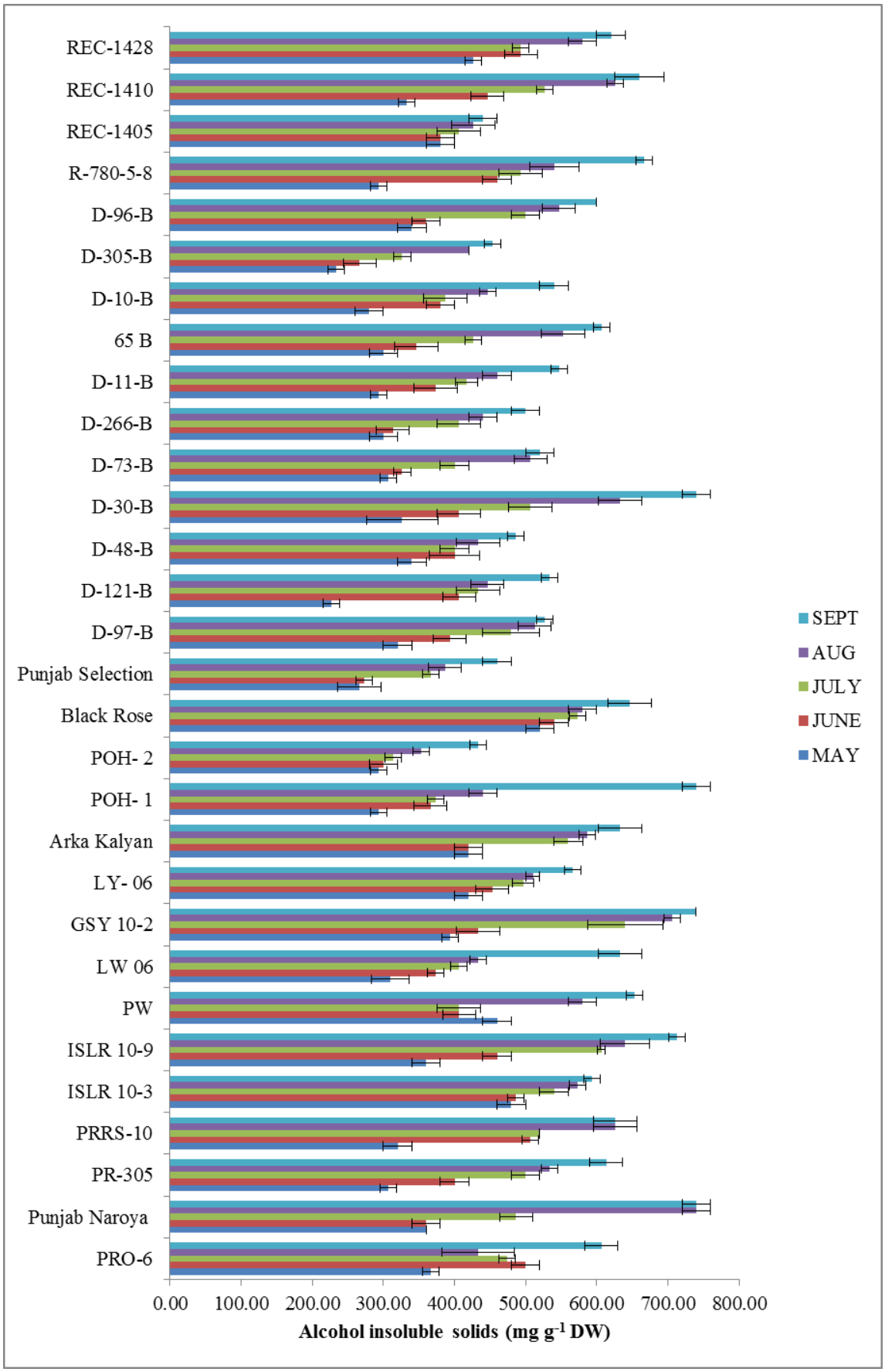

Fig 3: Alcohol insoluble solids content (mg g^{-1} DW) in thirty varieties of onion (*Allium cepa* L.) at different time intervals

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