RESEARCH ARTICLE

MATURITY INDICES OF SWEET SORGHUM '*WANI*' VARIETY UTILIZED IN *PAUK* PROCESSING

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Abstract: Sorghum is considered as versatile crop, use for; feed, food and industrial purpose. *Rabi* sweet sorghum '*wani'* variety was reported for *pauk* purpose. Green, tender, roasted and threshed clean grain of sweet sorghum is known as *pauk*. Experiment related to maturity of *wani* was carried out at MSRS-NAU, Surat with four treatments and seven replications in simple RBC design. Non-significant change was observed in plant height (2429±1mm); plant leaves (8Nos), top stalk length (678±1.5mm) and top stalk weight (112±1.21g) between 90–120DAS. Maximum length, diameter, volume, weight of head, were observed significantly high at 110DAS with value 292mm, 60.3mm, 2800ml and 106.8g, respectively. Mean diameter, sphericity, weight of thousand grains, volume of thousand grains and bulk density of grain were observed 3.33±0.7mm, 0.6954±0.023, 28±7.1g, 22.7±2.2cc and 1.217±0.212g/cc, respectively with elliptical shape. At 110DAS, all sensory parameters were recorded significantly high and then reduced, except tenderness. Proximate composition increased where as the moisture and sugars of plant as well as grain reduced with respect to maturity. Plant hormones like; GA changes with respect to maturity where as IAA and ABA was found increasing. These plant hormones could be determined using derived equations. Result related to maturity of *wani* revelled that, sorghum was at its maximum physical, biochemical and physiological maturity between 90–120DAS. Further, the sweet sorghum grain could be processed for *pauk* processing purpose between 90–110DAS otherwise it loose its quality. The collected maturity related data could be useful for further studies on *pauk* processing and its machineries development.

Keyword: Sweet Sorghum, *Wani*, Maturity Indices, *Hurda*, *Pauk*, GA

INTRODUCTION

Agriculture was the key activity and contributed about 4.1% of total world GDP, since last few years. Sorghum *(Sorghum bicolor* L. Moench*)* is having native Africa continent and now available almost worldwide. The word "sorghum" was derived from "*sorgo*", an Italian name for a plant. Perhaps 80 percent of India's cultivated sorghums also known as "*durras*" have dominant type in Ethiopia, North Africa, and along the Sahara's southern fringes (Anonymous, 2010). Sorghum has great potential because of its physiological marvel due to; highest dry matter accumulation rates and quickest maturing food plants which thrive on many marginal sites like; water logging, saline, hot & dry and drought conditions. It is the world's most versatile crop because of it's used for culinary purpose and value added product. Even though, it was included in the list of "lost-crops of Africa", due to 48.12% and 47.44% reduction in sorghum production and area, respectively within last ten years (Anonymous, 1996; www.fao.org).

The sorghum is planted normally in the month of July-October and harvested during January-March. Optimum growth of sorghum occurs at about 30°C (www.sorghumtrust.co.za). It is grown for food, fodder and industrial crop of dry land and poor soil agriculture (Madhusudhana, *et al*., 2017). Food purpose, grain sorghum goes through nine distinct stages of development after emergence, out of that stages from seven to nine are considered to be most critical and important for grin purpose sorghum. Each stage takes about 20 to 30 days and gets mature by about 120 to 140 days (Gerik, et al., 2003).

In Gujarat, it occupied an area of about 0.8lakh hectares with a productivity of 1265kg/ha during 2018-19 (www.indiastate.com). In Gujarat, the sorghum is mainly grown for feed and fodder during *kharif* season while for grain (seed) during *rabi* season. The grains (seeds) of sorghum at soft dough stage i.e. before physical maturity are green, tender, sweet, watery, and tasty as food. Green, tender, roasted and threshed clean grain of sweet sorghum is known as *pauk* or *hurda*. (Pandit and Varsheny, 2019). The cleaned tender green but roasted sweet sorghum grains are used to consume in various way in Gujarat, Rajasthan and Maharashtra (Patil, et. al., 2013; Chavan, *et al*., 2013 and Mitchell, 2018). The *Wani* was reported as one of the important variety of sorghum, which has 30 % glycogen. Little information with respect to its maturity characteristics and measures of plant and grain in concern to *pauk* processing purpose are available. There for a systematic experiment was set to generated information related to maturity and harvesting indices for green tender sweet sorghum grain or pauk processing.

MATERIALS AND METHODOLOGY

The experiment for identification of sweet sorghum plant and grain maturity was conducted at Main Sorghum Research Station, Navsari Agricultural

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University, Navsari as per standard lay out using simple randomized block design (RBD) layout and various properties of sweet sorghum crop as well as its grain were evaluated with respect to days after sprouting (DAS) as treatment and seven replications for two years to identify maturity indices for *pauk* processing purpose.

Various dimensions of sweet sorghum stalk, head, stem and grain were using digital vernier calliper (Make: Mitutoyo Crop. Model: CD-12"C, Range: 0-300 mm, Least Count: 0.01 mm). The sphericity, volume, density and geographical mean diameter were measured as method described by Mohsenin (1986) for finalizing the shape of head. Weight was measured using digital weighing balance (Make: Citizen Weighing System, Model: Scale-Tec 6 Kg, Range: 25 g- 6 kg, Least Count: 0.5 g). The moisture, ash, fiber, fat, protein and carbohydrate content of plant as well as grain was analysed as per the method described by Ranganna, (2009) and Berwal, et al. (2004).

Phytohormones were estimated using method described by Li, *et al*. (2011) with some modification to support the physical data. A mobile phase of sample for GA, IAA and ABA was prepared using mixture of methanol (60%) and acetic acid (0.2%) as well as organic extract from 100 mg sweet sorghum grain from panicles in 0.5 ml propanol-H_2O-concentrated HCl (2:1:0.002 v/v/v), 1 ml dichloromethane, 1 ml of 80% methanol included centrifugation and filtration through 0.22 µm. Detection and quantification of phytohormones was done on Prominence UFLC, high performance liquid chromatogram (HPLC) equipped with PDA detector 2800 and C-18 column at a flow rate of 0.600 ml min^{-1} based on an isocratic program at 208 nm as well as 265 nm UV visible detectors using standard solution of GA, IAA and ABA (Figure – 1).

RESULTS AND DISCUSSION

The table–1 showed the various measures related to plant, stalk, head and stem of sweet sorghum *Wani* variety known for *pauk* purpose cultivar in Gujarat.

Non-significant data was observed for plant height, no of leaves in a plant, top stalk length and top stalk weight during maturation period, The results in table-1 as well as figure–2a and 2c clearly said that the plant was at its maximum physical dimensions in terms of plant height (2432mm), numbers of leaves in a plant (8 Nos), top stalk length (680 mm) and top stalk weight (114 g) between 90 to 120 days after sprouting (DAS). Masane, et al. (2016) reported similar research work results for popular *pauk* purpose sweet sorghum variety *Ashwini*. Generally, top portion of the plant stalk is known as head or cob while bottom portion called stem. It was observed that, the length, diameter, volume as well as weight of stalk head, first increased up to 110 DAS and then reduced slightly. Results shown in figure–1a and 2c indicated that the stalk head length, diameter, volume and weight of head were significantly high at 110 DAS. Same figure showed that physical properties; stem length and stem diameter was increased during development stage. The stem length (43 mm) and stem diameter (7.6 mm) were significantly high or at par with highest measurement on 110 DAS. German (2016) reported relationship between size, weight with area, density, as well as various properties of grain.

The biochemical composition and moisture content of sweet sorghum plant between 90 and 120 days after sprouting presented in table–1 and figure–2b and 2d. The moisture content of stalk head, stalk stem, grain, and husk was observed between 42.54 % to 29.96 %, 42.54 % to 29.96 %, 67.45 % to 51.99 % and 27.65 % to 23.49 %, respectively. Gadakh, et al. (2013) indicated similar moisture value for post rainy season sorghum verities. It was noted that, the total carbohydrate, total protein, total fat, total fibre, and total ash value for sweet sorghum plant increased from 44.57 % to 57.57 %, from 11.16 % to 12.06 %, from 1.15 % to 1.25 %, from 31.0 % to 34.0 %, and from 5.7 % to 7.3 %, respectively. On the basis of that, the calculated calorific value for sorghum plant was also increased from 219 cal/100g to 276 cal/100g. Results are presented in Figure – 2b and 2d. Data indicated the significant mean values for each individual biochemical composition and moisture content of sweet sorghum plant between 90 to 120 DAS. Dharmaputra, et al. (2012) has reported similar results for biochemical composition for sorghum variety after maturity of crop. The highest moisture content was reported at initial maturity stage at 90 DAS of plant and then it became dry significantly with respect to moisture content of stalk head, stem, grain and husk.

The plant hormones like; Gibberellic Acid or Gibberellins (GA or GA_3), Indole Acetic Acid (IAA) and Abscisic Acid (ABA) plays important role in the development of grain as well as plant parts. Figure–2e described the behaviour of sweet sorghum stalk head during the period of maturation with respect to selective plant hormones. The data in Table-1 indicated that, GA increased from about 3030 ng/g to 3576 ng/g and then reduced to 260 ng/g during maturation days of sweet sorghum. IAA and ABA increased from the value of 103 ng/g and 178 ng/g to 576 ng/g and 426 ng/g, respectively between the maturation periods from 90 to 120 DAS. GA followed the third order polynomial trend described in equation–1 with best fit correlation coefficient value R^2 = 1.00. The IAA and ABA increased by following linear trend descried in equation–2 and equation–3 with best fit correlation coefficient value R^2 =0.98 and R^2 = 0.94, respectively.

$$Y_{GA} = 0.372X^3 - 131.1X^2 + 15043X - 56031$$

……eqn.1

$$Y_{IAA} = 16.28X - 1387$$

……eqn.2

$$Y_{ABA} = 7.809X - 553$$

……eqn.3

Where,

Y_{GA} = Concentration of GA, ng/g.
Y_{IAA} = Concentration of IAA, ng/g
Y_{ABA} = Concentration of ABA, ng/g
X = Days after sprouting, Day.

The beginning of fall in value of Gibberellins (GA) was indicated the initiation of senesces of grain. The indicated critical point was observed on 110 days of sprouting. Srivastava, (2002) and David, *et al*. (2008) have described that, the before peak period called pre-maturation period while after peak period post-maturation.

The combine effect of increase in biochemical composition, decrease in moisture content as well as change in hormones were significantly observed on physiological and physical maturity of plant between 90 to 120 DAS. The data related to plant maturity proved that the sweet sorghum plant was become physically mature between 90 to 120 days, but up to 110 days found to be the best physiological maturity period for sweet sorghum after sprouting for *pauk* processing.

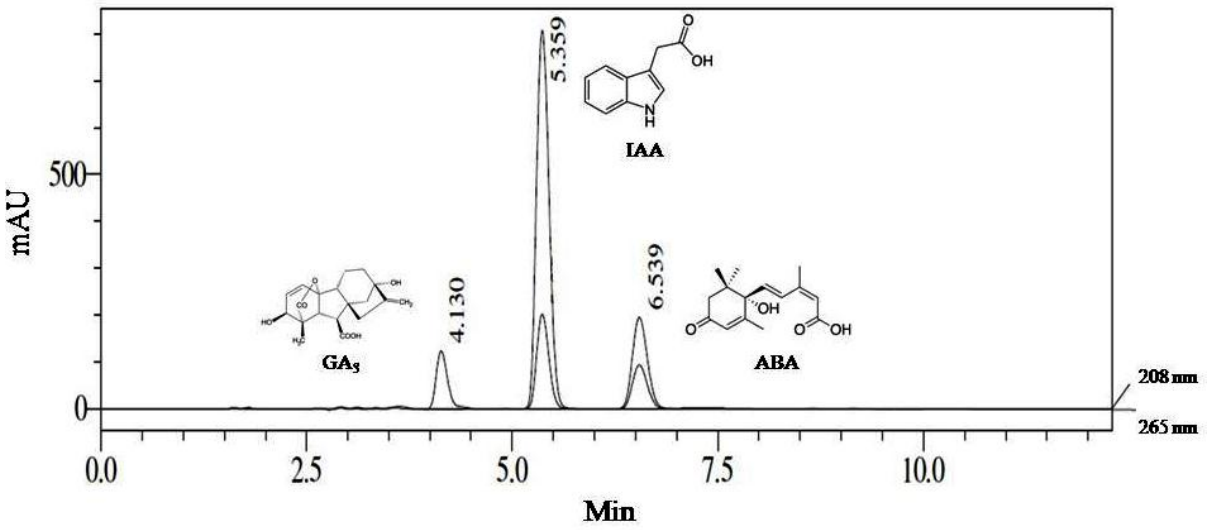
The roasted immature green and tender grain or grain of sorghum is known as *pauk* or *hurda*. table-2 showed the data related to physical, biochemical and sensory parameters of sweet sorghum grain between 90 to 120 DAS. The major axe of the grain increased with DAS from 3.8 mm to 5.5 mm and lastly reduced by 0.1 mm. The primary minor as well as secondary minor axis also increased from 3.9 mm to 4.9 mm and then reduced by 0.2 mm as well as increased from 1.2 mm to 2.4 mm and decreased by 0.2 mm, respectively. The geometric mean diameter of sweet sorghum grain was initially increased from 2.6 mm to 4.0 mm and then reduced by 0.3 mm, similar trend was reflected in case of sphericity, which increased from 0.6753 to 0.7212 but at the last reduced to 0.6915 during 90 to 120 DAS. The shape of the grain was observed elliptical during all these four stage. Rooney (2009) have reported similar trend of physical properties of grain for sorghum. Figure-2f represented that, the weight of thousand grains increased from 20.9 g to 35.1 g and then reduced to 31.4 g, where as the volume of thousand grain increased from 20.5 cc to 24.8 cc and decreased up to 23.9 cc. Table-2 represented that, the bulk density also increased from 1,005 g/cc to 1.429 g/cc and then reduced to 1.323 g/cc. all the measures related to grain like; grain dimensions, weight and volume of 1000 grains, density of grain, etc. were found significantly high at 110 DAS. Masane, *et al*. (2016) has reported the results in line of this outcome for PKV-*Ashwini* variety of sorghum.

Figure-2g showed that the proximate components of grain like; total carbohydrate, total protein, total fat, total ash and total fibre increased from 65.08% to 87.08% from 10.56% to 13.77%, from 1.19% to 1.86%, from 0.68% to 0.74% and from 0.40% to 0.46% respectively. Significantly highest value was observed at 120 DAS for total carbohydrates, total protein, total fat, total ash and total fibre. Shinde, *et al*. (2016) has shown similar presentation in their research data for *rabi* sorghum variety for tender grain processing. The moisture content, total sugar, total reducing sugar and non-reducing sugar of grain decreased from 67.45% to 54.99%, from 12.11% to 11.76%, from 1.06% to 0.76% and 11.67% to 11.50%, respectively. Significantly highest moisture content, total sugar, reducing sugar and non-reducing sugar was recorded at 90 DAS. It was also observed that the reduction in moisture content was less up to 110 DAS but then it reduced very much. Same trend was observed with all types of sugar also. Tonapi, et. al. (2006) and Atnavathi, *et al*. (2016) have reported similar trend for various biochemical properties of sorghum during maturation. Against that increased in proximate composition was fast up to 110 days after sprouting but then after that only slight increased in values observed. Above discussion lead to conclusion that, sweet sorghum grain achieved its biochemical maturity up to 100 DAS then it became fully matured and then travel toward senescence.

Table-2 also described the sensory score for taste, colour, flavor, tenderness and overall acceptability for grain *pauk* collected by using 9-point hedonic scale. The hedonic score for taste, colour, flavour and overall acceptability were increased from 5.6 to 8.8, 5.9 to 8.9, 5.6 to 8.8 and 6.9 to 8.9 between 90 to 110 DAS followed by reduction up to 8.4, 7.4, 8.2 and 7.5, respectively. Only for tenderness, the hedonic score was observed highest at 90DAS with value 8.9 and then reduced up to 6.5 on 120DAS. Bar chart in figure-2h revelled that the significantly highest quality scored was recorded at 110 DAS for taste, colour, flavour and overall acceptability, while it found significant high at 90 DAS only for tenderness. These data also revealed that grain maturity stage between 90 to 110 days for sensory accepted quality score. Similar observation was reported by Mitchell, (2008) for food grain sorghum verity and reported that, sweet ness initially increased but after physical maturity reduced and same reflected in sensory evaluation. The taste, colour and flavour reflect the change in chemical composition of grain as well as physiological changes occurred during the development stage of grain from 90 to 120 DAS, the tenderness of grain reflects the change in moisture content and physical maturity stage with respect to development stage. The overall acceptability score reflects the combined effects of chemical compositional change, moisture change, physical

maturity as well as physiological maturity change in grain.

The experiment lead the overall conclusion that, the sweet sorghum could be processed for *pank* or *hurda* processing purpose between 90 to 110 days after sprouting after that, it loose its quality. Previous research done by Chavan, *et al*. (2009); (2014); Masane, *et al*., (2016) and Shinde, *et al*., (2016) also found in the line of derived conclusion and reported the maturity days for *hurda* or *pank* purpose sweet sorghum crop after 90 days of sprouting.



Note: Values on Y-axis and at top of peak shows wavelength and time, respectively.

Figure-1: Standard run for GA, IAA and ABA in HPLC for detection of plant hormones.

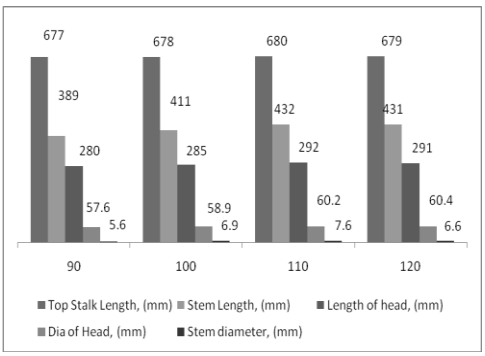
Table 1. Change in various properties of sweet sorghum plant with respect to days after sprouting.

Particular	90 DAS	100 DAS	110 DAS	120 DAS	Mean	SEM ±	CD @ 5%	CV%	TxY
Plant Height, (mm)	2429	2431	2432	2431	2431	0.954	NS	0.55	NS
No of Leaf	8	8	8	8	8	0.182	NS	8.50	NS
Top Stalk Length, (mm)	677	678	680	679	679	0.398	NS	0.22	NS
Top Stalk Weight, (g)	113	114	112	112	113	0.599	NS	1.99	NS
Length of Head, (mm)	280	284	**292**	291	287	0.288	0.82	0.39	NS
Diameter of Head, (mm)	57.6	58.9	**60.4**	60.3	59.28	0.185	0.53	1.22	NS
Head Volume, (ml)	2488	2644	2800	**2867**	2700	19.546	55.92	2.82	NS
Head Weight, (g)	80.1	93.5	**106.8**	104.0	95.468	0.903	2.58	3.40	NS
Stem Length, (mm)	389	411	432	**433**	416	0.357	1.607	0.07	NS
Stem diameter, (mm)	5.6	6.9	**7.6**	6.7	6.713	0.411	NS	8.43	NS
Head M.C. (%)	**65.29**	60.99	54.31	47.62	57.054	0.811	2.319	5.53	NS
Stem M.C. (%)	**42.54**	41.06	35.49	29.96	36.186	0.008	0.02	0.008	NS
Grain M.C. (%)	**67.45**	63.12	58.76	51.99	60.332	0.339	0.97	2.19	NS
Husk M.C. (%)	**27.65**	25.92	24.22	23.49	25.321	0.214	0.61	3.29	NS
Carbohydrate, (%)	44.57	48.90	53.24	**57.57**	47.571	0.427	1.82	3.36	NS
Protein, (%)	11.16	11.46	11.76	**12.06**	11.614	0.035	0.15	1.12	NS
Fat, (%)	1.15	1.18	1.22	**1.25**	1.198	0.003	0.01	0.83	NS
Ash, (%)	5.7	6.3	6.8	**7.3**	6.521	0.025	0.11	1.45	NS
Fiber, (%)	31.0	32.0	33.0	**34.0**	32.981	0.083	0.35	0.71	NS

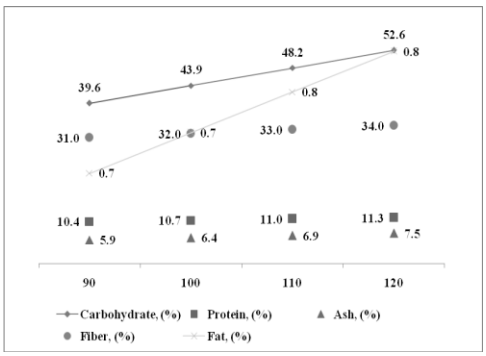
Calories (Cal/100g)	219	238	257	**276**	247.522	2.676	1.14	3.42	NS
GA (ng/g)	3020.4	5240.7	3576.8	262.4	3025.08				
IAA (ng/g)	103.2	200.7	409.4	576.60	322.488				
ABA (ng/g)	178.4	252.9	289.8	426.40	286.88				

Table 2. Change in various properties of sweet sorghum grain with respect to days after sprouting.

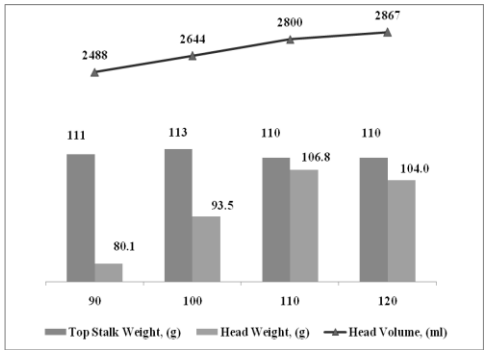
Days After Sprouting	90	100	110	120	Mean	SEM ±	CD @ 5%	CV%	TxY
Major axis, (mm)	3.8	4.4	**5.5**	5.4	4.8	0.043	0.123	3.5	NS
Primary minor axis, (mm)	3.9	4.2	**4.9**	4.7	4.4	0.023	0.066	2.02	NS
Secondary minor axis, (mm)	1.2	1.5	**2.4**	2.2	1.8	0.023	0.067	4.98	NS
Seed Diameter, (mm)	2.6	3.0	**4.0**	3.7	3.7	0.031	0.089	3.63	NS
Seed Sphericity	0.6753	0.6920	**0.7212**	0.6915	0.6950	0.0068	0.0196	3.81	NS
1000 count Seed Weight (g)	20.9	25.5	**35.1**	31.4	28.098	0.463	1.32	6.41	NS
1000 count Seed Volume (cc)	20.5	23.6	**24.8**	23.9	23.214	0.192	0.55	3.20	NS
Bulk Density of Seed (g/cc)	1.005	1.080	**1.429**	1.323	1.209	0.022	0.06	6394	NS
Total Carbohydrate %	65.08	72.41	79.75	**87.08**	76.079	0.086	0.366	0.42	NS
Total Protein %	10.56	12.59	13.63	**13.77**	12.886	0.05	0.14	1.51	NS
Total Fat %	1.19	1.34	1.78	**1.86**	1.545	0.03	0.13	5.42	NS
Total Ash %	0.68	0.70	0.74	**0.74**	0.726	0.078	NS	19.49	NS
Total Fiber %	0.40	0.41	0.44	**0.46**	0.427	0.009	0.02	7.74	NS
MC of grain (%)	67.45	63.12	58.76	51.99	60.332	0.339	0.97	2.19	NS
Total Sugar, %	12.11	11.99	11.88	11.76	11.937	0.0035	0.015	0.071	NS
Total Reducing Sugar, %	1.06	0.96	0.86	0.76	0.907	0.0032	0.012	1.10	NS
Total Non-Reducing Sugar, %	11.67	11.61	11.56	11.50	11.585	0.0035	0.015	0.051	NS
Taste (9 point scale)	5.6	6.8	**8.8**	8.4	7.4	0.137	0.39	7.15	NS
Colour (9 point scale)	5.9	7.7	**8.9**	7.4	7.5	0.172	0.49	8.95	NS
Flavour (9 point scale)	5.6	7.9	**8.8**	8.2	7.6	0.139	0.40	6.99	NS
Tenderness (9 point scale)	**8.9**	**8.9**	8.0	6.5	8.1	0.150	0.43	7.13	NS
Overall Acceptability (9 point scale)	6.9	8.6	**8.9**	7.5	8.0	0.161	0.46	7.79	NS



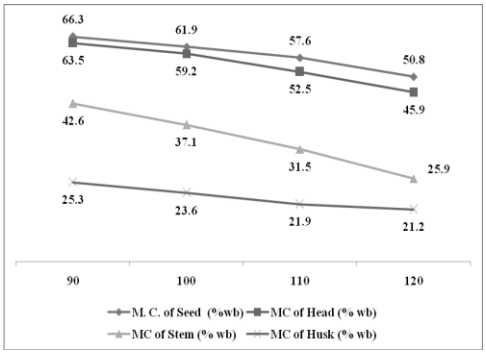
a) Dimensions of stalk, stem and head



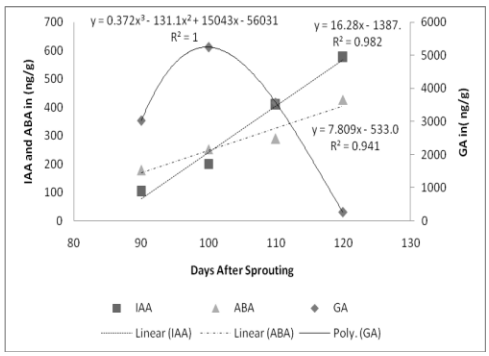
b) Proximate composition of plant



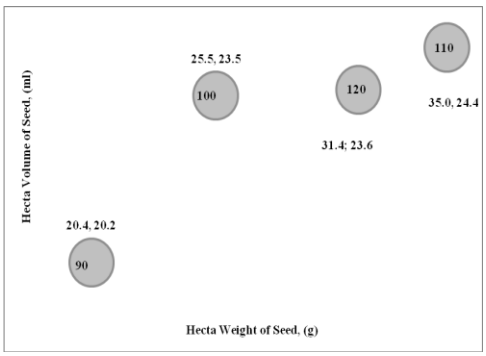
c) Weight of stalk, head and head volume



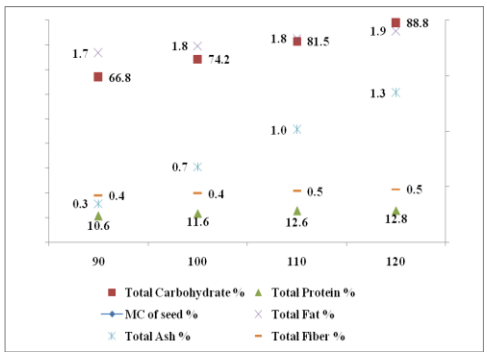
d) MC of stem, head, grain and husk



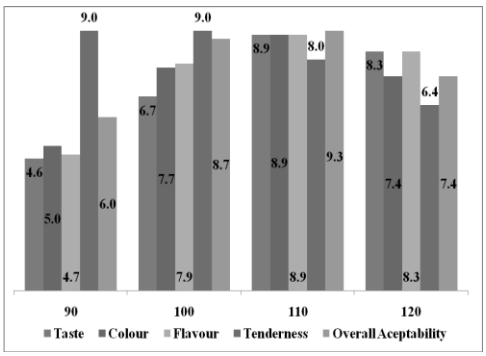
e) AAA, ABA and GA in stalk bud



f) Weight and volume of 1000 grains



g) proximate composition of grain



h) Sensory score of grain

Figure 1: Various measures of sweet sorghum stalk, head and grain during maturation period.

CONCLUSION

Sorghum is considered as versatile crop, use for; feed, food and industrial purpose. Non change in plant height, plant leaves, top stalk length, and top stalk weight were observed after development stage–VI. The maximum length, diameter, volume, weight of head, were observed with value 292mm, 60.3mm, 2800ml and 106.8g, respectively during maturity period. Mean diameter, sphericity, weight of thousand grains, volume of thousand grain and bulk density of grain were observed 3.33±0.7mm, 0.6954±0.023, 28±7.1g, 22.7±2.2cc and 1.217±0.212g/cc, respectively. Shape of grain was observed elliptical. Best sensory quality characteristics were observed at 110DAS. Phytohormones like; GA, IAA and ABA during maturity was found increasing, except GA. These plant hormones could be determined using derived equations. Result related to maturity of *wani* revelled that, plant and grain were at its maximum physical, biochemical and physiological maturity between 90–120DAS. Further, the sweet sorghum grain could be processed for *pauk* processing purpose between 90–110DAS otherwise it loose its quality. The collected maturity related data could be useful for further studies on design and development of *pauk* processing machineries.

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