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GENOTYPIC VARIATION BETWEEN DIFFERENT CULTIVARS OF *CAJANUS CAJAN* (L.) ON CARBOHYDRATE AND NITROGEN FRACTIONS

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ABSTRACT

Twelve genotypes of pigeonpea (Cajanus cajan (L.) Millspaugh) which were divided into three groups based on the duration for flower initiation i.e. Short duration (ICPL151, ICPL87, ICPL1, ICPL6), Medium duration (T21, HY2 mutant, Pusa agheti, C11) and Long duration (ICPL270, ST1, PDM1, LRG30) were selected and was raised at the Experimental Farm of the Department of Botany, Andhra University, Waltair, Visakhapatnam, A.P., India for the present study on carbohydrate and nitrogen fractions. The decrease in sugar content accompanied by an increase in starch content in developing pigeonpea seeds from 10 to 30 days. The ICPL87 of short duration and the HY2 mutant of medium duration recorded the highest and lowest per cent values of reducing sugar content among the total genotypes studied. The soluble nitrogen content of the seeds increased up to 20 days after flowering, with a reduction at 30 days followed by a slight increase at the harvest period. However, among the genotypes the ICPL87 of short duration, the T21 of medium duration and the PDM1 of long duration genotypes recorded the greater values of total nitrogen content in their respective groups.

KEY WORDS

Genotypes, pigeonpea, starch, soluble nitrogen, sugar content.

INTRODUCTION

In grain crops, the economically important part of the plant is the mature seed. Varietal differences in physiological and biochemical changes of developing pods and seeds have been described in a number of legumes such as pea (Flinn and Pate,1968), soyabean (Egli,1975; Wein and Ackah,1978; Egli *et al*., 1981,1984; Fraser *et al*., 1982; Guldan and Brun, 1985; Swank *et al*., 1987), french bean (Carr and Skene, 1961; Crookston *et al.,* 1974), field bean (Barratt, 1982), urd bean (Anita Saha, 1987), mungbean (Dhillon and Nainawatee, 1990), bambarra ground nut (Sreeramulu *et al*.,1992) and pigeonpea (Singh *et al.,* 1980; Balakrishnan *et al*., 1984; Singh *et al*., 1984).

Carbohydrates and proteins are the main constituents of many legume seeds. During the maturation of seeds, these constituents are stored in the cells of the cotyledons (Bewley and Black, 1983). Although legume seed proteins have been the subject of numerous studies in the past, only limited information is available on various legume starches (Leach et al., 1959; Schoch and Maywald, 1968; Lai and Varriano-Marston, 1979; Yang et al., 1980; Tjahjadi and Breene, 1984). Generally, the whole seed in pigeonpea genotypes contains 48 to 59 per cent of starch (ICRISAT, 1976). Little information is available on the nutritional aspects of pigeonpea genotypes belonging to different maturity groups. Singh (1984) reported that protein and starch together constituted 75 per cent of total dhal (split seeds without seeds coat) weight. Only a small variation was observed between genotypes in starch and soluble sugar content of early, medium and late maturity groups. It was also observed that the starch content is less in high protein genotypes when compared to the others. On the other

hand, soluble sugar content varied among pigeonpea genotypes (Singh et al., 1990).

Nitrogen containing compounds play an important role in plant growth and development (Beevers, 1976; Bray, 1983). In addition to proteins, the nitrogen content of seed comprises certain amount of free amino acids, amides, amines, nucleic acids, alkaloids and other related substances. Pandey and Pant (1979) reported the distribution of non-protein N, protein N and different protein fractions in early, medium and late maturing pigeonpea genotypes and concluded that the levels of different nitrogenous constituents could not be used to characterise the various genotypes. The seed protein content differed significantly among the pigeonpea genotypes (Singh and Eggum, 1984; Jain et al., 1986).

Comparative studies in the quality characteristics of early and late maturing varieties of pigeonpea revealed that early maturing genotypes had high seed protein content than late maturing ones (Thripathi et al., 1975). The seed protein content was positively associated with seed yield in late maturing genotypes when compared to early and medium maturing genotypes (Laxman Singh et al., 1977). However, Dahiya and Brar (1976) found no evidence of significant correlation between 100-seed weight and seed protein content. The protein supplementation value of grain legumes in cereal based diets is well recognized. Developing seeds of legumes exhibits continuous protein synthesis reaching a peak followed by a decline associated with decreasing seed water content. Keeping in this view, twelve pigeonpea genotypes were compared on carbohydrate and nitrogen fractions.

MATERIAL AND METHODS

Twelve genotypes of pigeonpea (*Cajanus cajan* (L.) Millspaugh) were selected for the investigation which were divided into three groups based on the duration for flower initiation and is presented in the following table:

Group	Genotypes
Short duration	ICPL151, ICPL87, ICPL1, ICPL6
Medium duration	T21, HY2 mutant, Pusa agheti, C11
Long duration	ICPL270, ST1, PDM1, LRG30

The seeds were obtained from International Crops Research Institute for the Semi-Arid Tropics, Patancheru, All India Co-ordinated Pulse Improvement Programme, Hyderabad and other places of Andhra Pradesh. The pigeonpea crop was raised at the Experimental Farm of the Department of Botany, Andhra University, Waltair, Visakhapatnam, A.P., India. The Experimental Farm is situated in a congenial place on latitude 17^o 35' north and longitude 83^o 17' 8" east and at 100 feet high above mean sea level. The crop was grown for three seasons. Seeds of pigeonpea were inoculated with Rhizobium and were sown 4 cm deep in the plots of 10X10 m with a spacing of 75 cm between the rows and 50 cm between the plants within the rows, every growth season of the years. The pigeonpea crop was grown as sole crop. In addition to rainfed conditions, the crop was subjected to monthly irrigation whenever required. The farm yard manure and fertilizers were supplied at the rates shown in the following table:

Manure/Fertilizer	Kgs/ha	No.of doses	Stages
Farm yard manure	5000	1	Soil incorporation
Nitrogen	25	1	Before sowing
Phosphorus	50	1	Before sowing

For recording the data on each parameter, ten plants were collected from each plot and the mean values were presented at monthly intervals. Finally, the mean value of all the three growth season data was given. The data collected and analyzed include both field observations and laboratory experiments.

Carbohydrate fractions

Carbohydrate fractions were estimated in the dry powders of leaves, stem, root and developing seeds separately in the 12 genotypes at different phases of growth.

Total soluble sugars and Starch: The total soluble sugars and starch were estimated according to the method of McCready et al. (1950) as modified by Clegg (1956). Soluble sugars were separated by alcohol extraction and the residue containing starch was brought into solution with perchloric acid.

Extraction sugars: Two hundred milligrams of dried and powdered plant material was homogenized in 10 ml boiling 80 per cent alcohol for 5 minutes and were

centrifuged. The residue was reextracted twice and the combined extracts were evaporated under reduced pressure. The remaining cloudy aqueous fractions were diluted with water and made up to known volume.

Extraction of starch: The residue saved was stirred continuously for 5 minutes with 5 ml of water and 6.5 ml of 52% perchloric acid and centrifuged. The residue was reextracted by adding one volume of water and made up to known volume.

Determination of sugars and starch

For estimation of sugars, 5 ml of anthrone reagent was added to each of the clean and dry test tubes placed in ice. Later 1 ml of the sugar extract was added to each test tube and the test tubes were kept shaking for 2-3 minutes and were allowed to stand in chilled conditions for another 3 minutes. Then the test tubes were placed in a boiling water bath and allowed to boil up to 12 minutes and cooled to room temperature. The same procedure was followed for the blank except for the sugar extract which was replaced by 1 ml of distilled water. Hundred per cent transmittance was adjusted using blank and the intensity of the green colour was read at 630 nm using ECIL'S Junior spectrophotometer GS 866C. Standard curve was prepared by using analar glucose to give a solution of 100 µg of glucose per ml. Conversion factor 0.9 was used to calculate the starch content since 0.9 g starch yields approximately 1 gram of glucose on hydrolysis.

Preparation of anthrone reagent

Anthrone reagent was prepared by dissolving 60 mg of anthrone in 30 ml of cold 95% (V/V) H_2SO_4. A fresh solution was prepared daily.

Reducing sugars

Total reducing sugars were estimated according to the phenol sulphuric acid method of Dubois et al. (1956) as followed by Smyth and Dugger (1980).

Extraction

Two hundred milligrams of plant material of different parts and the mature seeds of all the 12 genotypes were hydrolyzed separately using 5 ml of 0.5 N HCl at 100 ºC for 1 hour. The residue remaining after centrifugation was extracted further with 2 volumes of 0.5 N HCl. The reducing sugar content of the pooled extracts were determined relative to the standard glucose.

Estimation

A series of test tubes with internal diameter between 16 and 20 mm were taken to allow good mixing without dissipating the heat too rapidly. One ml of sugar solution was mixed with 1 ml of 5 % phenol and 5 ml of concentrated H_2SO_4. The stream of acid being directed against the liquid surface than against the sides of the test tubes in order to obtain good mixing. The tubes were allowed to stand for 10 minutes in a water bath at 30 ºC. A blank was prepared by substituting distilled water for the sugar solution. The absorbance of the characteristic yellow colour was measured at 490 nm using ECIL' S Junior spectrophotometer GS 866C. Standard reference curve was prepared using analar glucose to give a solution of 100 µg of glucose per ml.

Nitrogen fractions

Nitrogen fractions were estimated in the dry powders of the plant material separately in all genotypes at the selected phases of growth.

Total nitrogen

Total nitrogen was determined according to the method of Markham (1942). One gram of dried and powdered material was taken in a 25 ml micro-kjeldhal flask taking care not to all the material to stick to the sides of the flask. One gram of catalyst (a mixture of 1 g copper sulphate, 9 g potassium sulphate and 1 g selenium dioxide) was added for aiding digestion. Three ml of nitrogen-free analar sulphuric acid and 1 ml of hydrogen peroxide were also added to the sample and it was digested on a hot plate until a clear colourless solution was obtained. The volume of the solution was made up to 25 ml in a volumetric flask after digestion. Blank with reagents alone was also carried out simultaneously. Five ml of the aliquot of the digest was transferred to the distillation unit and 10 ml of 40% sodium hydroxide was added. This solution was distilled water for 20 min in the microkhjeldhal distillation apparatus. The ammonia liberated was absorbed into 2 ml of boric acid indicator mixture kept below in a conical flask. The completion of the distillation was recognized by the change in pH of the indicator in the receiver. The indicator solution was pink in the beginning and turned green at the end of complete distillation. The solution containing the indicator was titrated against N/100 HCl until pink colour appears. The amount of nitrogen present in the sample was calculated thus:

1ml of N/100 HCl = 0.14 mg of nitrogen.

Preparation of boric acid indicator mixture

The boric acid indicator mixture was prepared by mixing 10 g of boric acid 200 ml of absolute alcohol and 20 ml of indicator solution (indicator solution was prepared by mixing 0.033 g of bromocresol green and 0.666 g of

methyl red in 100 ml of absolute alcohol) in a litre flask and the final volume was made to 1 litre with distilled water. The pH of the solution was then adjusted to 5.0 to 5.1.

RESULTS

Carbohydrate fractions

Starch content per seed and per unit dry weight basis, showed a continuous increase up to 30 days after flowering in all the genotypes studied (Figs.-1,2,3). Thereafter, it showed slight variation towards the seed maturation. It appeared that rapid starch accumulation occurred during the period between 10 to 30 days after flowering. Among the genotypes studied, on per seed basis the ICPL87 (39.68 mg) of short duration, the Pusa agheti (38.50 mg) of medium duration and the ST1 (39.14 mg) of long duration genotypes recorded greater values of starch content till the end of the maturation period (Fig-1a, c, e). On unit dry weight basis, the ICPL87 (571.40 mg), the C11 (560.00 mg) and the PDM1 (598.70 mg) of short, medium and long duration genotypes respectively showed higher levels of starch content at the end of the seed maturation period (Fig-1b, d, f).

The figure 2 represents genotypic variation of soluble sugar content during seed development. The soluble sugar content when expressed on per seed basis, exhibited an increasing trend up to 30 days after flowering followed by a slight decline. In contrast, when the soluble sugar content was expressed on per unit dry weight basis, they showed a sharp decline from the 10^{th} day onwards. Among the short and medium duration genotypes studied, the ICPL87 of short duration and the C11 of medium duration showed greater values of soluble sugar content in both the expressions i.e., on per seed and per unit dry weight basis. However, in long duration genotypes, the ST1 showed greater values when expressed on per seed basis and the PDM1 showed greater values when expressed on unit dry weight basis.

The reducing sugar content of developing seeds of different genotypes was presented in figure 3 a,c,e. On per seed basis, all the genotypes showed a rapid accumulation of reducing sugar content until 30 days after flowering. Thereafter reducing sugar content was more or less constant until the harvest. Among the genotypes studied, the ICPL87 (3.30 mg/seed) of short duration, the C11 (2.53 mg/seed) of medium duration and the ST1 (2.75 mg/seed) of long duration genotypes exhibited greater values of reducing sugar content in their respective groups (Fig-3a, c, e).

On per unit dry weight basis all the genotypes showed a gradual decrease until the end of the maturation period. The reducing sugar content at the end of the maturation period ranged from 21.25 to 40.93 mg among the different genotypes. The ICPL270 of long duration and the ICPL6 of short duration genotypes recorded the minimum and maximum values of reducing sugar content respectively at the end of the seed maturation period (Fig- 3b, d, f).

Nitrogen fractions

The total nitrogen content per seed and per unit dry weight basis during seed development of pigeonpea genotypes were presented in figures 4a, b, c, d, e, f. Total nitrogen content per seed showed a continuous increase from the 10^{th} day after flowering until the time of harvest. The nitrogen content at the time of harvest showed a range of variation from 2.25 to 3.70 mg per seed among the genotypes studied. The ICPL87 of short duration genotypes exhibited the maximum value and the PDM1 of long duration genotypes the minimum value among the total genotypes studied (Fig-4a, c, e). On unit dry weight basis, the total nitrogen content in the developing seeds showed a gradual decrease from 10 to 30 days after flowering and then increased slightly at the end of the seed maturation period (Fig-4b, d, f). Among the genotypes the ICPL87 of short duration, the T21 of medium duration and the PDM1 of long duration genotypes recorded the greater values of total nitrogen content in their respective groups.

The genotypic variation in soluble nitrogen on per seed as well as on per unit dry weight basis during the seed development of pigeonpea were presented in figures 5a, b, c, d, e, f. The soluble nitrogen content on per seed basis, increased up to 20 days after flowering followed by a slight decrease up to 30 days and attaining higher values at the end of the maturation period. (Fig-5a, c, e). Among the genotypes, the maximum value of the soluble nitrogen content (0.91 mg per seed) was observed in ICPL270 and the minimum value in PDM1 (0.40 mg/seed), both belonging to the long duration group. On unit dry weight basis soluble nitrogen content of all the genotypes decreased up to 30 days after flowering followed by an increase until 40 days (Fig-5b, d, f). At the end of the seed maturation period the values of the soluble nitrogen content showed a range

of variation from 6.35 to 9.15 mg/g dry weight among the genotypes studied.

Genotypic variation in the protein content of the developing seeds of pigeonpea genotypes were plotted in figures 6a, b, c, d, e, f. The protein content on per seed basis showed a gradual increase up to the end of the seed maturation period in all the pigeonpea genotypes. The active accumulation of protein content in the seeds were observed between 10 to 30 days after flowering in all the genotypes (Fig-6a, c, e). The maximum (20.9 mg/seed) and minimum (13.18 mg/seed) protein contents among all the genotypes were observed in the ICPL270 and the PDM1 respectively both belonging to the long duration genotypes. On the other hand, on unit dry weight basis protein content in the developing seeds of pigeonpea genotypes showed a decrease up to 20 days after flowering, followed by a slight increase (Fig-6b, d, f). At the end of the seed maturation period, the ICPL87 (241.86 mg/g dry wt), the T21 (230.80 mg/g dry wt) and the PDM1 (222.50 mg/g dry wt) of short, medium and long duration genotypes respectively exhibited greater values in their respective groups.

Composition of mature seeds

The hundred seed fresh and dry weights among the genotypes varied greatly (Table-1). Among the genotypes, the ICPL151, Pusa agheti and ICPL270 of short, medium and long duration genotypes exhibited greater fresh and dry weight values in their respective groups. Among all the genotypes, the T21 showed the minimum fresh weight value and the PDM1 the minimum dry weight value.

The carbohydrate and nitrogen fractions of the embryo portion of mature seeds of different genotypes were given in Table-2. Among the genotypes, the starch content showed highest value of 60.08 per cent in PDM1 of long duration genotypes and lowest value of 50.48 per cent in HY2 mutant of medium duration genotypes. Soluble sugar content of the different genotypes varied between 3.37 to 4.88 per cent. The ICPL87 (4.62%), C11 (4.80%) and PDM1(4.88%) of short, medium and long duration genotypes exhibited higher per cent soluble sugar content respectively within their respective groups. The reducing sugar content of the genotypes studied varied between 2.68 to 3.95 per cent. The ICPL87 of short duration and the HY2 mutant of medium duration recorded the highest and lowest per cent values of reducing sugar content among the total genotypes studied.

The total nitrogen content showed a range of values between 3.76 to 4.41 per cent in all the genotypes studied. The maximum percentage of total nitrogen was recorded by the genotype ICPL87. The soluble nitrogen content values varied between 0.64 to 0.84 per cent in short duration genotypes, 0.56 to 0.85 percent in medium duration genotypes and 0.69 to 0.82 per cent in long duration genotypes studied. The HY2 mutant and C11 both belonging to medium duration genotypes showed the maximum and minimum values among the total genotypes studied. The total protein content in pigeonpea genotypes exhibited a range of values between 19.96 to 24.18 per cent. The ICPL87 of the short duration genotypes and the ST1 of long duration genotypes showed the maximum and minimum protein percentages in all the genotypes studied.

DISCUSSION

The increase in seed size showed a linear relationship with seed weight (Table-1). On the other hand, no significant correlation between 100-seed weight and seed protein content was observed in the pigeonpea genotypes studied (Table-2).

Table-1: Seed Weight of Pigeonpea Genotypes (Grams/100-Seeds) (Mean Of 10 Replications ± S.E.)

Genotype	Fresh weight	Dry weight
	Short duration	
ICPL151	10.84 ± 0.25	9.97 ± 0.15
ICPL 87	9.89 ± 0.19	9.02 ± 0.11
ICPL1	7.00 ± 0.18	6.55 ± 0.12
ICPL6	7.55 ± 0.20	6.95 ± 0.13
	Medium duration	
T21	6.82 ± 0.18	6.55 ± 0.11
HY2 mutant	9.80 ± 0.23	8.97 ± 0.12
Pusa agheti	10.85 ± 0.30	10.24 ± 0.21
C11	9.08 ± 0.21	8.34 ± 0.19
	Long duration	
ICPL270	10.98 ± 0.28	10.17 ± 0.18
ST1	9.71 ± 0.18	9.25 ± 0.11
PDM1	6.91 ± 0.17	5.52 ± 0.09
LRG30	7.36 ± 0.19	6.97 ± 0.11

Table-2: Carbohydrate and nitrogen fractions of the mature seeds (per cent) of pigeonpea genotypes (cotyledons plus embryonic axis) (mean of 3 replications ±S.E.)

Carbohydrate fractions				**Nitrogen fractions**		
Genotypes	**Starch**	**Soluble sugars**	**Reducing sugars**	**Total nitrogen**	**Soluble nitrogen**	**Protein**
Short duration						
ICPL151	56.33±4.01	3.81±0.13	3.75±0.11	3.92 ±0.08	0.64±0.02	21.87±1.02
ICPL 87	58.04±3.88	4.62±0.18	3.95±0.10	4.41±0.12	0.84±0.02	24.18±0.90
ICPL1	54.67±2.67	4.12±0.19	3.90±0.10	3.78±0.13	0.80±0.04	20.10±0.88
ICPL6	57.23±2.19	4.37±0.21	4.13±0.09	3.85±0.07	0.74±0.03	21.37±0.95
Medium duration						
T21	55.31 ±2.65	3.70±0.16	2.98±0.06	4.25±0.09	0.81±0.02	23.08±1.05
HY2 mutant	50.48±1.98	3.69±0.13	2.68±0.16	3.98±0.11	0.85±0.05	21.09±1.02
Pusaagheti	55.65±2.53	3.37±0.18	2.81±0.08	4.13±0.06	0.75±0.06	22.64±0.89
C11	56.10±2.88	4.80±0.19	3.00±0.07	3.90±0.11	0.56±0.02	22.05±0.79
Long duration						
ICPL 270	54.98 ±2.73	3.56±0.15	2.19±0.08	4.08±0.14	0.82±0.03	20.52±0.86
ST1	54.87±3.79	4.30±0.19	3.15±0.09	3.76±0.09	0.75±0.04	19.96±0.85
PDM1	60.08±4.15	4.88±0.20	3.42±0.10	3.99±0.09	0.69±0.03	22.25±0.92
LRG30	57.50±3.50	4.28±0.14	3.75±0.09	4.01±0.11	0.75±0.04	21.67±0.88

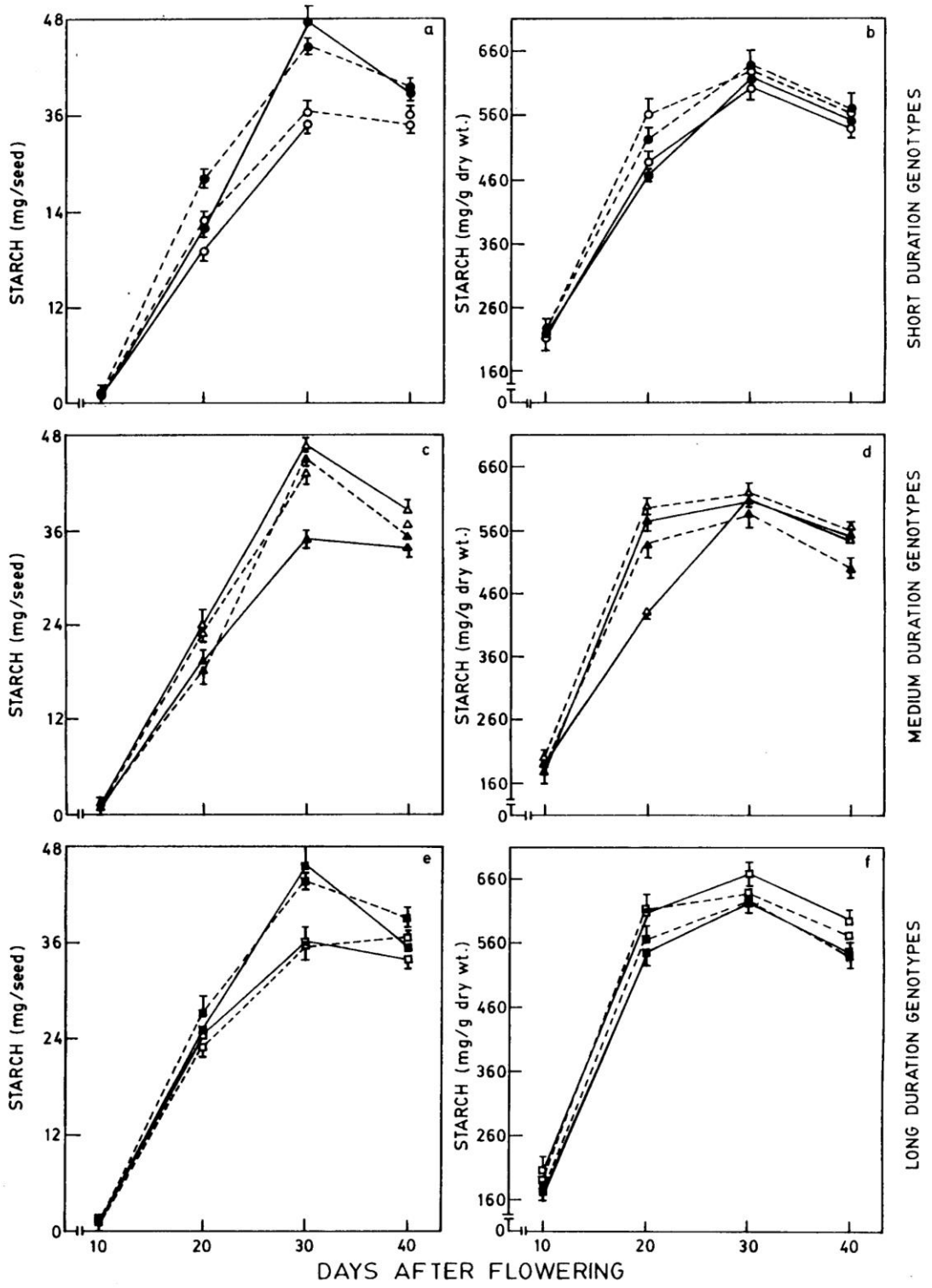

Fig.-1: Starch content of the developing seeds of pigeonpea genotypes. (Vertical bars represent S.E.)
●–––● ICPL151;●---● ICPL87;o––o ICPL1;o---o ICPL6; ▲––▲ T21; ▲---▲ HY2 mutant;Δ---Δ Pusa agheti;Δ––Δ C11; ■––■ ICPL270; ■---■ ST1;□––□ PDM1;□---□LRG30

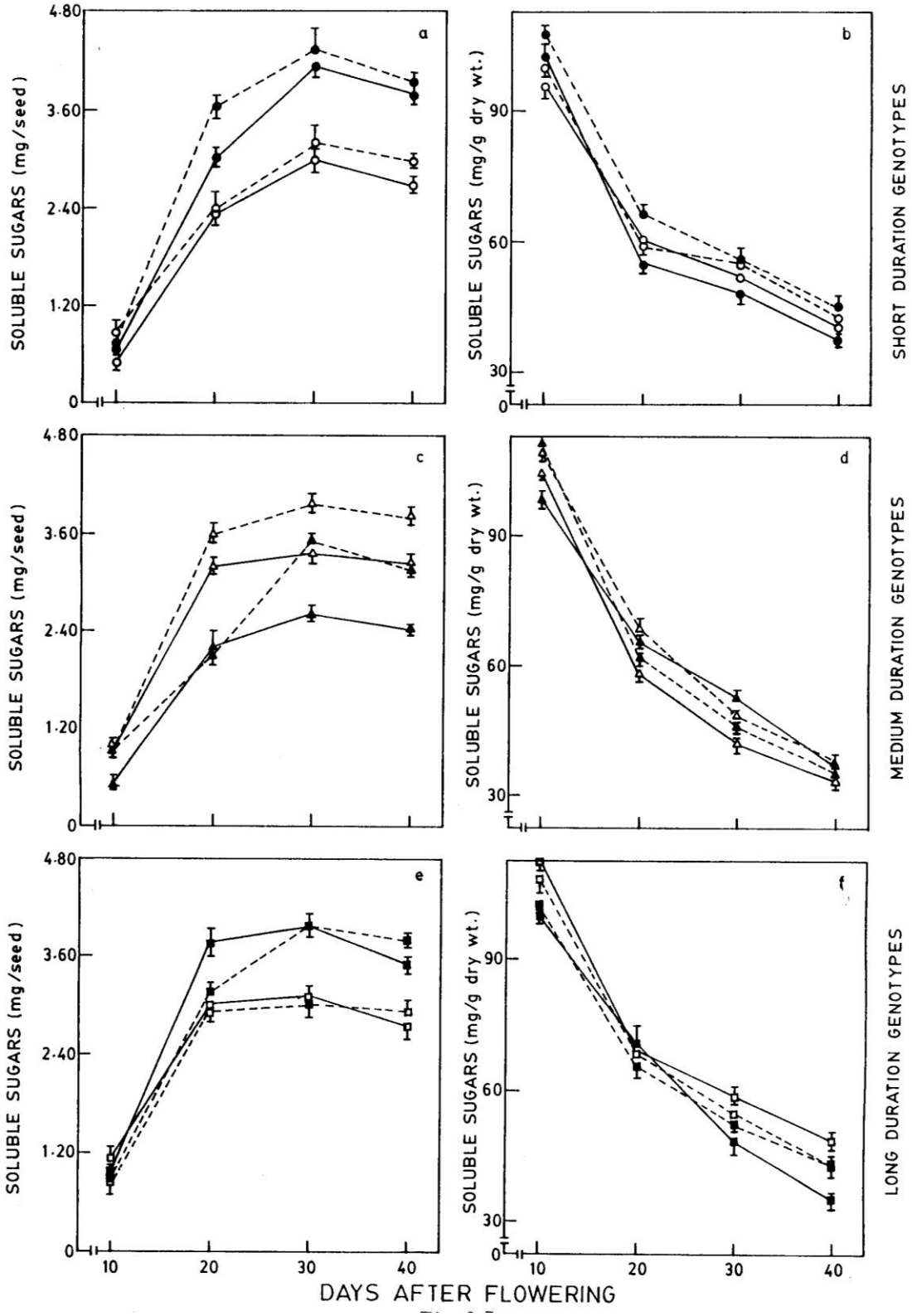

Fig. -2: Soluble sugar content of the developing seeds of pigeonpea genotypes. (Vertical bars represent S.E.)

●—● ICPL151;●---● ICPL87;o—o ICPL1;o---o ICPL6; ▲—▲ T21; ▲---▲ HY2 mutant;Δ---Δ Pusa agheti;Δ—Δ C11; ■—■ ICPL270; ■---■ ST1; □—□ PDM1; □---□LRG30

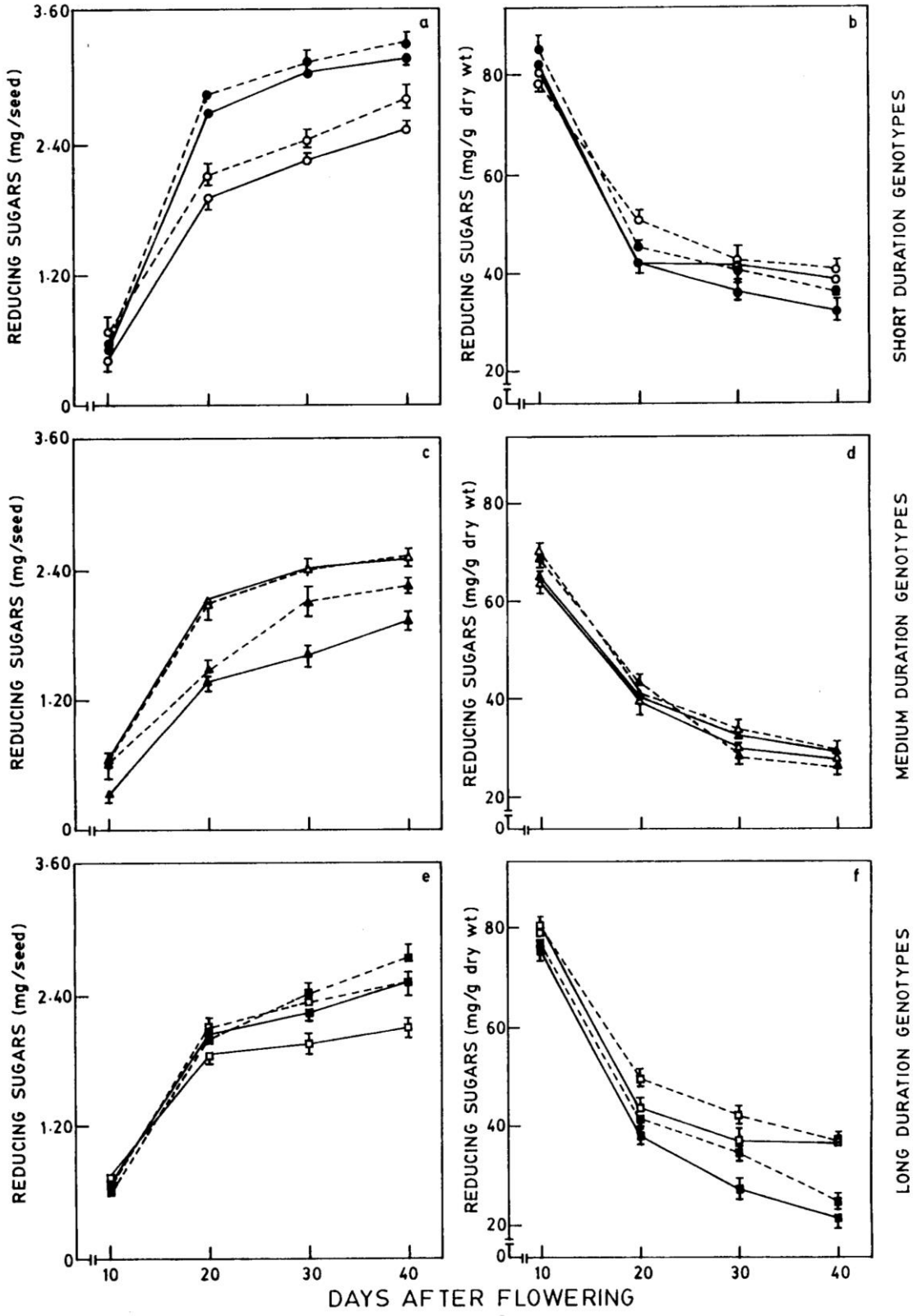

Fig. -3: Reducing sugar content of the developing seeds of pigeonpea genotypes. (Vertical bars represent S.E.)
●—● ICPL151;●---● ICPL87;o—o ICPL1;o---o ICPL6; ▲—▲ T21; ▲---▲ HY2 mutant;Δ---Δ Pusa agheti;Δ—Δ C11; ■—■ ICPL270; ■---■ ST1; □—□ PDM1; □---□LRG30

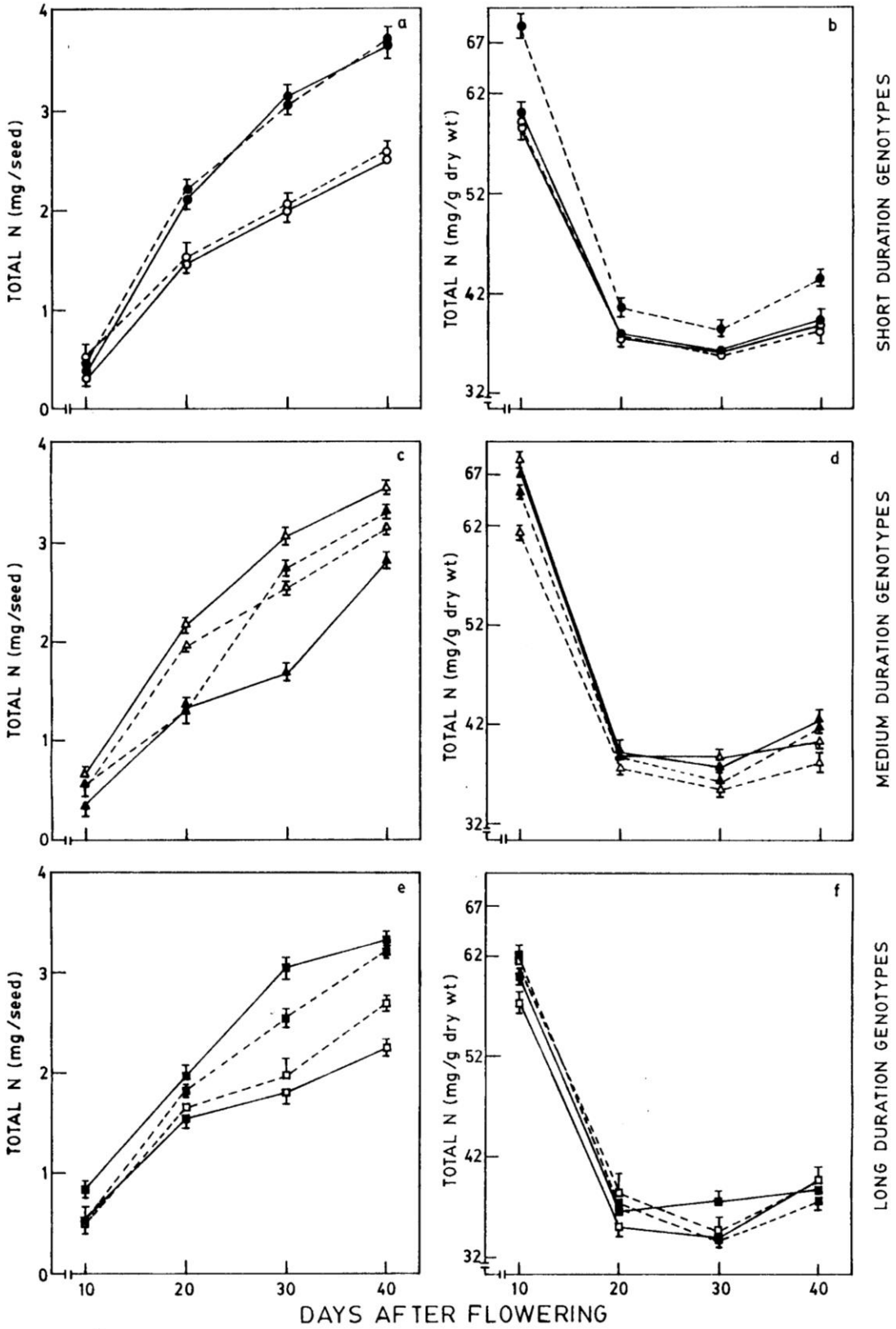

Fig.-4: Total nitrogen content of the developing seeds of pigeonpea genotypes. (Vertical bars represent S.E.)

●—● ICPL151;●---● ICPL87;o—o ICPL1;o---o ICPL6; ▲—▲ T21; ▲---▲ HY2 mutant;Δ---Δ Pusa agheti;Δ—Δ C11; ■—■ ICPL270; ■---■ ST1; □—□ PDM1; □---□LRG30

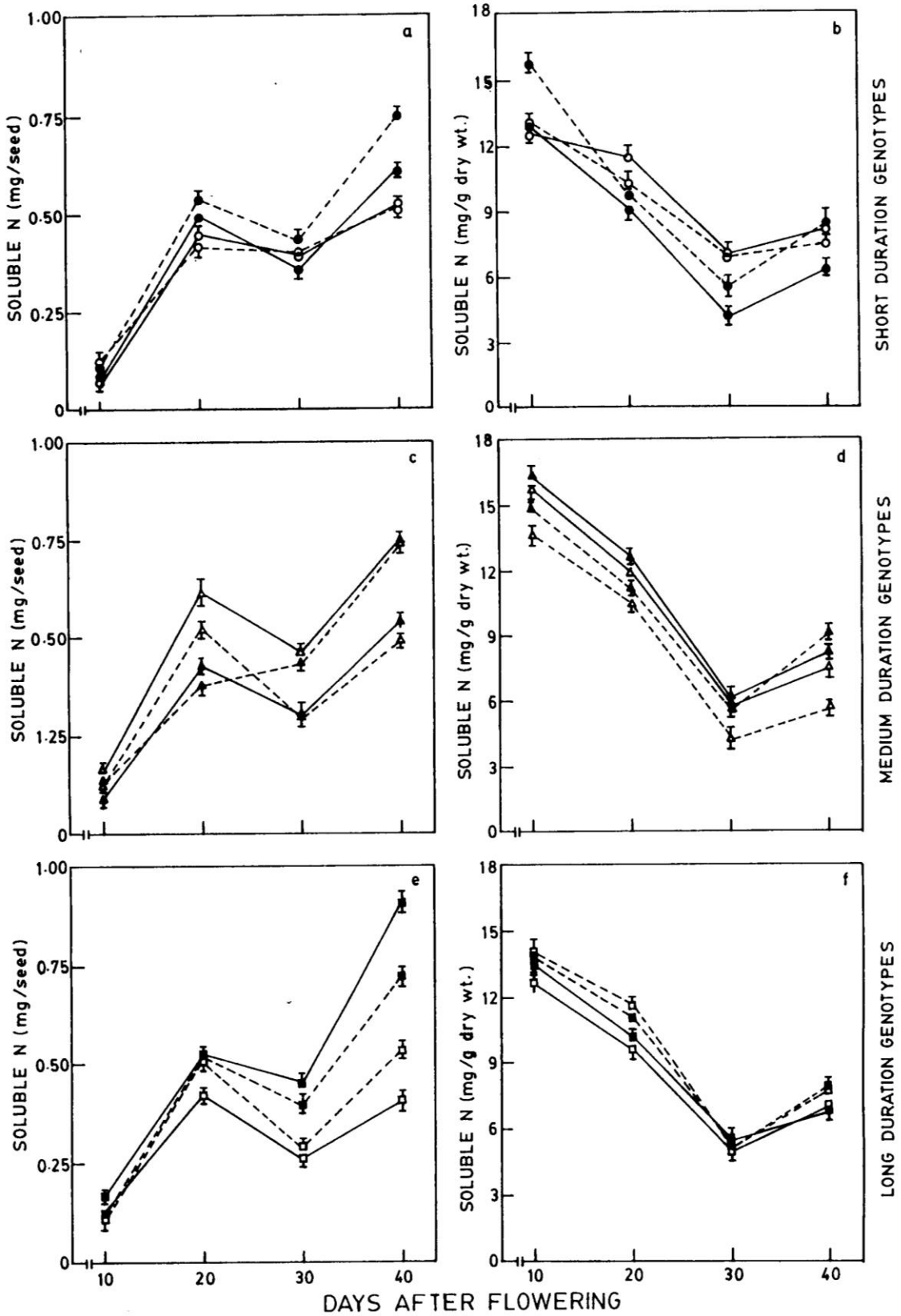

Fig. -5: Soluble nitrogen content of the developing seeds of pigeonpea genotypes. (Vertical bars represent S.E.)
●—● ICPL151;●---● ICPL87;o—o ICPL1;o---o ICPL6; ▲—▲ T21; ▲---▲ HY2 mutant;Δ---Δ Pusa agheti;Δ—Δ C11;■—■ ICPL270;■---■ ST1;□—□ PDM1;□---□LRG30

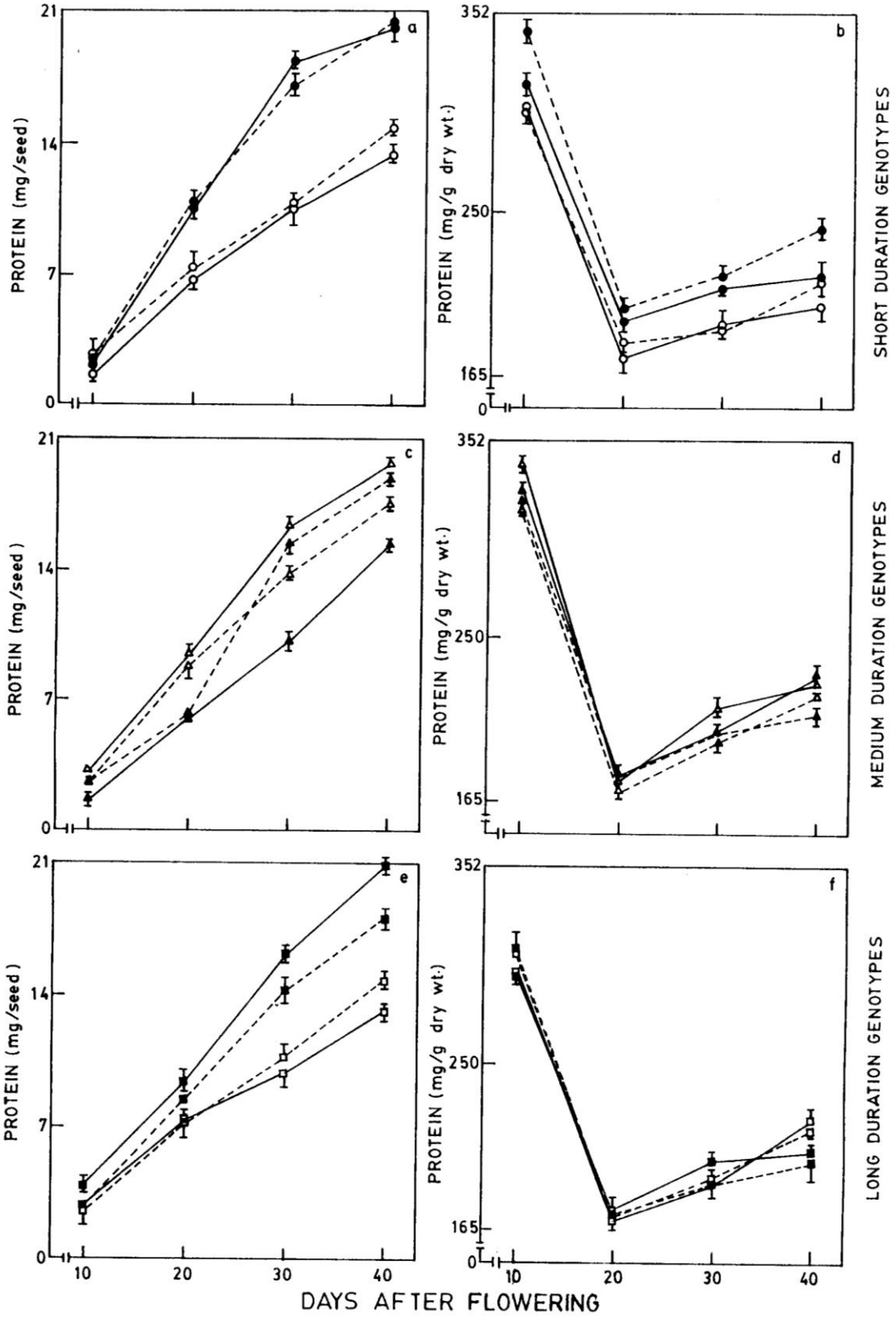

Fig.-6: Protein content of the developing seeds of pigeonpea genotypes. (Vertical bars represent S.E.)

●—● ICPL151;●---● ICPL87;o—o ICPL1;o---o ICPL6; ▲—▲ T21;▲---▲ HY2 mutant;Δ---Δ Pusa agheti;Δ—Δ C11;■—■ ICPL270;■---■ ST1;□—□ PDM1;□---□LRG30

Rapid accumulation of starch in all of the pigeonpea genotypes occurred during the period from 10 and 30 days after flowering (Fig-1a, b, c, d, e, f). The increase in starch is correlated with dry matter accumulation in the seeds. Extended period of starch accumulation commensurating with dry weight of seeds during major part of the seed development was also found in *Cicer arietinum* (Singh et al., 1981), in field beans (Barratt, 1982) and in bambarra groundnut (Sreeramulu et al., 1992). The soluble sugars and reducing sugars increased from 10 to 30 days after flowering followed by a decrease at maturity when expressed on per seed basis (Figs.-2a, c, e; 3a, c, e). However, the soluble and reducing sugar contents exhibited a gradual decrease from the 10th day after flowering until the end of the seed maturation period when expressed on unit dry weight basis (Figs.-2b, d f; 3b, d, f). The soluble and reducing sugar contents were closely related to the changes in seed water content and per cent moisture (Bain and Mercer, 1966; Rauf, 1978; Sreeramulu et al., 1992). The decrease in sugar content accompanied by an increase in starch content in developing pigeonpea seeds from 10 to 30 days (Figs.-2b, d, f; 3b, d, f) may probably indicate the utilization of sugars for starch synthesis (Bain and Mercer, 1966).

The total nitrogen content of the developing seeds, increased up to 30 days after flowering and more or less remained constant until the end of the maturation in all the pigeonpea genotypes (Fig-4 a, c, e). The soluble nitrogen content of the seeds increased up to 20 days after flowering, with a reduction at 30 days followed by a slight increase at the harvest period (Fig-5a, c, e). The decrease in soluble nitrogen content between 20 and 30 days indicated the possibility of higher rate of utilization of amino acids for protein synthesis. The protein content of the seeds showed a gradual increase up to 40 days after flowering (Fig-6a, c, e). The large seeded genotypes exhibited higher values of all nitrogen fractions when compared to small seeded genotypes. Most of the nitrogen in the young legume seeds appears to be soluble at the early developmental stages and declined with seed maturation (Bewley and Black, 1983). The sharp decline of soluble nitrogen was associated with a rapid increase in protein content during the seed development in all the pigeonpea genotypes studied. Similar relationship was observed in *Vicia faba* genotypes (Barratt, 1982).

The carbohydrate and nitrogen fractions other than protein did not show marked variations among the genotypes of pigeonpea. Differences if any are small. Therefore, these constituents may not be of considerable interest in characterizing various genotypes (Pandey and Pant, 1979). Hanway and Weber (1971) also did not find marked genotypic variation in the total nitrogen content of eight soybean and six groundnut genotypes. Interestingly, protein content of pigeonpea showed significant genotypic variation ranging from 19.96 to 24.18 per cent (Table-2). The short duration genotypes expressed higher values of seed protein content than long duration pigeonpea genotypes (Tripathi et al., 1975).

CONCLUSIONS

Rapid accumulation of starch, soluble sugars and reducing sugars were observed in the seeds between 10 and 30 days after flowering in all the pigeonpea genotypes. The total nitrogen and protein contents showed a gradual increase throughout the seed development. The soluble nitrogen content of the developing seeds increased up to 20 days after flowering with a reduction at 30 days and again showing an increase up to 40 days. The carbohydrate and nitrogen fractions showed some variations among the pigeonpea genotypes studied.

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