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GROWTH AND YIELD COMPARISON OF PERENNIAL GRASSES AS RAINFED FODDER PRODUCTION

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Abstract

Ten perennial fodder grasses were compared for growth and yield at New Developmental Farm, Agricultural University at Peshawar, Pakistan during 2006 and 2007. Tufts were transplanted on 16-02-2006 at 50 cm distance in 3 x 3 m plots replicated 4 times in RCB design. Fertilizer was applied 60 and 30 kg ha^{-1} as N and P using urea and SSP respectively. Results revealed that on 2 years average data, *Pennisetum purpureum* was highest in fresh matter, followed by *Setaria anceps* than any other grass while *Panicum maximum* showed the lowest fresh matter. The sequential dry matter growths against time of all grasses were in agreement with total dry matter yield with highest for *Panicum typhoides*, followed by with a non-significant difference with *Sorghum almum*, and *Setaria anceps*. Crop growth (CG) and mean of the growth rate with plant height were also in close association. Culm density did not vary as much as reported in dry matter and yield of the 10 species from each other. Grass *Digitaria decumbense* were lower in dry matter and plant height but found relatively denser than any other grass in the group. Grasses having highest dry matter were the highest in showing the leaf area index and showed the highest radiation use efficiency. Among the leaf and stem fraction of culms, grasses (e.g. *P. typhoides and S. almum)* showing the highest dry matter among the group and is termed as superior in growth and fodder yield. The study suggests that *P. purpureum, P. typhoides* and *S. almum* are relatively high potential grasses for cultivation at marginal and low fertile lands under rainfed condition yielding good fodder through judicious utilization of the available solar light per unit ground area.

Introduction

Fodder shortage does exist since long ago and is increased with recent rapid population growth in Pakistan. It has remained one of the major limiting factors of livestock production in the country (Bhatti, 1996). Currently, it is grown on about 12.6% of the total cropped area which is insufficient for the existing livestock population. According to an estimate, diversity does exist in productivity of fodder with more than one ton per hectare in Bannu, Swat, Peshawar, Malakand and Mardan, with about 1.0 to 0.5 t ha^{-1} in Nowshera, Charsada, Karak, Lakkimarwat and Kohat and less than 0.1 t ha^{-1} per animal in the hilly areas like Chitral, Batagram, and Abbotabad etc. Animals' performance depends on the amount and quality of green fodder and its availability within the different months during the year (Hatam *et al*., 2001). Grasses, due to adaptation and acclimatization to climate and soil, are advantageous than other plant species due to their surface rooting system (February & Higgins, 2010).

Grass morphology can be conceptualized as a hierarchical arrangement of structural modules also called tiller (Briske, 1991) which is group of phytomers (Robson *et al*., 1988) consisting of leaf blade, sheath, internodes, node and associated auxiliary bud (Moore & Moser, 1995). The ability of bud allows grass to re-generate (Krishna *et al*., 1984). Tiller initiation and development is basic unit of production and can correlate well to the vegetative period of grass in agro-climatic condition to extend its multi-cut and perennially in the area as efficient biomass producer. The only available source is the cultivable waste land that could be effectively brought under cultivation for green fodder production in an area. It creates space for the research to test new species that perform relatively better with prevailing conditions e.g. drought and hot summer and can contribute in green fodder on relatively marginal lands in the area. Experiments need to be conducted for green fodder improvement through identifying potential species, appropriate variety selection with performance on marginal lands under drought as perennial fodder that is effective in resource conservation i.e. solar light and natural precipitation with minimal nutrients at relatively poor fertile soils. The crop height and structure influence both forage quality and feed intake while crop growth represents plant morphology i.e. leaf to stem ratio. The study aims to evaluate perennial grasses for growth, biomass production and light use efficiency at marginal lands as drought resistant crop.

Materials and Methods

Field experiment was conducted at Agronomy Research Farm, Agriculture University Peshawar, Pakistan (lat. 34º01'N, log. 72^{o} E and 288 m height from sea) during summer 2006 and 2007. Soil of the experimental site is clay loam, low in organic matters (1.05%) and alkaline (pH 7.88). Nitrogen (N) content of the soil was low (0.099%). Daily solar radiation (incident radiation) was recorded at experimental site on the farm. Daily mean incident radiation during the study period was 16.85±5.37 and 17.08±5.69 MJ m^2, temperatures maximum 33.90±6.12 and 32.67±6.68, temperature minimum 19.93±6.60 and 19.93±6.68ºC during 2006 and 2007, respectively. The total water including rainfall was applied about 183 and 177mm in 2006 and 2007, respectively.

The experiment was conducted in randomized complete block design (RCBD) having four replications. Tufts of ten perennial grasses (Table 1) were transplanted on February 16, 2006. Before transplanting, seed bed was prepared and fertilizer was applied @ 60 and 30 kg ha^{-1} N and P from urea and SSP sources, respectively once at start of the growth. About fifteen cm long tufts were transplanted at 50 cm distances within rows by placing at 60º slanting positions. Each experimental unit comprised of 6 rows of three meter length yielding net plot of 3 x 3 m square. Plantation was done at optimum field moisture contents. All other required agronomic practices were provided uniformly during the early establishment of 60 days growth. Thereafter, irrigation, weeding etc. were stopped to establish drought for the rest of the growth period.

Table 1. Name of the perennial grasses with brief morphological features.

Botanical name	Common name	Brief morphological features
Setaria anceps	Setaria grass	Originated from Kenya, tufted perennial, stem ca 2 m high, compressed white glabrous, lower part leaves up to 40 cm long. Highly palatable fodder
Chloris gayana	Rhodes grass	Originated from Kenya, fine stem leafy prostate to erect turf forming up to 1.5m height, palatable and good for hay but not for silage
Pennisetum purpureum	Elephant grass	Originated from Tanzania, Tall, erect, thick stems up to 4.5m height. Not very good for fodder
Digitaria decumbense	Pangola grass	Originated from West Indies, semi-erect, stem up to 1m tall, forms open turf, pasture grass, with stands tramping and grazing nature
Digitaria swazilandensis	Finger grass	Originated from Zimbabwe, profusely branched, stem up to 60 cm height, grows on poor soils, tolerate drought stress, a good soil binder grass
Panicum maximum	Green panic grass	Originated from Tanzania, tufted perennial up to 3.5m tall, very succulent and nutrition's, it is suitable for mix seeding with legumes
Vetiveria zizynoides	Vetivar grass	Profusely branches stem up to 60cm, panicle dense, suitable for mix seeding with legumes
Panicum colaratum	Kleinpanic grass	Africa origen, tufted erect, sometimes with long spreading stolons. Stems 2-4 mm in diameter, and culms 0.3-1.5 m tall at maturity
Pennisetum typhoides	Napier Hybrid Bajra	Origen from Malawi, culms up to 3 m tall. Leaf laminae up to 1 m long and 7 cm wide. Panicle 4 cm.–2 in. long, subglobose to linear; rhachis cylindrical, villous; involucre persistent, borne upon stipe 1–25 mm
Sorghum almum	Columbus grass	From Argentina, Tall, robust perennial tetraploid, spreading short stout rhizomes; culms normally about 2-4 m tall, leaves resembling those of Johnson-grass but wider, waxy, 30–100 cm long, 5–4 cm broad; heads longer, lax, more spreading

Sampling and measurement: For fresh and dry matters yield, half meter row length samples at 2 locations were harvested for total 142 and 124 days growth in 2006 and 2007, respectively. Fresh matter was weighed in field. About one kg homogeneous sample was oven dried at 70ºC for not less than 60 h for dry matter determination. Sprouts density was also measured at final harvest in two central rows by placing ring of known size. Periodic samples of fresh matters during re-growth in 2007 were harvested at 10 days interval starting from early May. Total six harvests were taken during growth. The periodic dry matter was regressed against days after cut using non-linear regression (Eq. 1; Richard's, 1959). Mean crop growth rates (CGR) for the total growth period was derived as ratio of dry matter and time taken in days.

$$\text{Yield} = A / (1+B * \text{Exp}(-C X)) \qquad \text{Eq. 1}$$

Leaf area index (LAI) was recorded non-destructively using leaf area machine (LI-2000, LI-COR, USA). Fraction of radiation intercepted (FRI) was measured at ten days interval over the plants using quantum sensors (Sky PAR, ELE, UK). Ten instantaneous measurements were recorded and averaged for a mean reading by placing sensor above, below and over the plant canopy at 11-13 h to record irradiance (I), reflectance (R) and transmittance (T). While recording light, LAI and dry matters were also measured at similar location in an experimental unit. Potosynthetically Active Radiation (PAR) was derived by multiplying daily solar radiation with 0.47 (Akmal & Janssens, 2004; Akmal *et al*., 2010). FRI for a treatment and replication were derived using the following equation (Eq.2).

$$\text{FRI} = (I-R-T) / I \qquad \text{Eq. 2}$$

PAR from sprouting to the corresponding samplings were accumulated and multiplied with FRI values obtained from Eq. 2. Periodic dry matter was regressed with cumulated FRI absorbed by the grasses and slope of the regression was termed as radiation use efficiency (RUE). Ten representative tillers of species were randomly selected and dissected in to leaf and stem fraction. Both fractions were separately dried and weighed for determination of the leaf to stem ratio. The same tillers were also measured for height measurement data.

Results and Discussion

Name of the grasses with brief morphological features are shown in Table 1. Fresh matter (FM), as expected, was observed different for the different grasses (Table 2). *Pennisetum purpureum* showed the highest FM, followed by *Setaria anceps*, *Panicum typhoides* and *Panicum coloratum.* The lowest FM was observed for *Digitaria decumbanse*. Similarly, maximum dry mater (DM) was reported for *Panicum typhoides* that did not differ than other grasses e.g. S*etaria anceps*, *Sorghum almum*, *Pennisetum purpurem* and *Panicum coloratum.* The lowest DM was observed for *Digitaria swazilandensis.* Perennial grasses have different growth habit and their response to environments is different (Langer, 1979). Differences in FM and DM of grasses are due to differences in the growth habit and morphology which differentiate grass in biomass production from one another (Ullah *et al*., 2006). Yield variations are due to assimilates allocation in different organs and its partitioning in above ground parts (Bandara *et al*., 1999). The highest stem fraction and/or broader leaves contribute towards the highest DM. Moreover, differences in FM and DM of a grass are due to different water content in biomass. Solid versus hollow stem and crude fiber contents also make differences among grasses biomass.

Table 2. Growth comparison study of ten perennial grasses for rainfed fodder production at Peshawar during 2006 and 2007 (n = 8).

S. No	Grass species	FM (gm^{-2})	DM (gm^{-2})	Plant height (cm $tiller^{-1}$)	Sprouts density (10 cm^{-2})	Stem weight (g)	Leaf weight (g)	LAI	LSR	RUE (g MJ^{-1})
1.	*S. anceps*	4850 b	1180.3 ab	93 bc	58.08 c	0.66 de	0.61 de	1.51 c	1.02 ab	1.17 a
2.	*C. gayana*	1925 e	774.1 cde	78 d	56.00 c	0.51 def	0.43 de f	1.22 d	0.80 cd	0.81 e
3.	*P. purpureum*	7608 a	948.8 bcd	94 bc	58.08 c	0.58 cd	0.70 cd	1.95 a	0.83 cd	0.94 cd
4.	*D. decumbense*	1218 f	482.7 ef	58 f	106.08 a	0.21 f	0.17 f	1.65 bc	0.83 bcd	0.56 g
5.	*D. swazilandensis*	1750 e	0420.9 f	66 e	80.00 b	0.33 ef	0.38 ef	1.53 c	1.11 a	0.71 f
6.	*P. maximum*	1638 ef	0554.1 ef	88 c	69.92 b	0.69 de	0.60 de	1.62 c	0.85 bcd	0.93 d
7.	*V. zizynoides*	2700 d	657.8 def	107 a	56.00 c	1.23 bc	0.99 bc	1.58 c	0.80 cd	1.02 bc
8.	*P. coloratum*	2925 d	927.5 bcd	111 a	50.08 c	1.19 bc	0.72 cd	1.11 d	0.72 d	0.98 cd
9.	*P. typhoides*	5000 b	1292.5 a	98 b	58.08 c	2.12 a	1.43 a	1.93 a	0.80 cd	1.11 ab
10.	*S. almum*	3750 c	1076.0 abc	111 a	53.92 c	1.32 b	1.06 b	1.82 ab	0.91 bc	1.10 ab
	LSD for years	234.40	143.60	2.92	05.08	0.19	0.13	0.07	0.08	0.02
	LSD for species	524.14	321.09	6.64	11.37	0.43	0.30	0.17	0.18	0.07
	LSD for interaction	689.87	510.59	8.89	15.60	0.61	0.41	0.28	0.28	0.28

Means followed by different letters within a column are significantly ($p<0.05$) different from each other.

Mean tiller's height (TH) was observed the maximum for *Panicum coloratum,* followed by *Sorghum almum* and *Vetiveria zizynoides.* All three grasses did not differ ($p<0.05$) from each other in TH. The lowest TH was observed for *Digitaria decumbense.* Differences within grass tillers' height are well known because different grasses have responded differently to the environment and climate due to variation in growth and biomass production that makes the canopy structure (Akmal, 1997). Amanullah *et al*., (2004) reported variation in sorghum varieties of a common species. Size of meristematic zone and rate of cell production are mainly contributed in increasing tiller height and is the consequent of variations in TH of the different grasses (Guevara *et al*., 2002).

ANOVA results indicated that grasses were different ($p<0.05$) in shoot density (SD) with the highest for *Digitaria decumbanse* followed by *Digitaria swazilandensis* and *Panicum maximum.* The lowest SD was observed for *Panicum coloratum.* Shoot density of the different species was found different ($p<0.05$) from each other due to differences in growth and canopy morphology. This difference in shoot density of grasses may correlate to the genetic makeup (Kim, 1990). Dry leaf weight (LW) was the highest for *Panicum typhoides,* followed by other grasses like *Sorghum almum*, V*etiveria ziznoides*, *Panicum coloratum* with the lowest *for Digitaria decumbanse.* Likewise, dry stem weight (SW) was the highest for *Panicum typhoides* followed by *Sorghum almum* and *Vetiveria ziznoides* and the lowest for *Digitaria decumbanse*. Leaf to stem ratio (LSR) is also important parameters of the forage grasses and observed the highest for *Digitaria swazilandensis, Setaria anceps, Sorghum almum, Panicum maximum, Digitaria decumbense, Pennisetum purpureum, Chloris gayana* and *Panicum typhoides. However,* LSR of these grasses did not differ from each other. The minimum LSR was reported for *Panicum coloratum.* The difference in leaf and stem dry weight is due to differences in assimilates contribution for biomass allocation in the plant organs. The higher the stem fraction of a grass might have higher dry matter development but poor fodder quality due to high fiber contribution. Leaf size, area and number are major attributes altering leaf and stem fraction of the grasses. Grasses have higher leaf than stem is terms as high quality fodder (Kammann *et al*., 2005). The different LSR may also be attributed to their adoptability with climatic condition, growth and canopy structures under the growing condition. These results are in agreement with those reported by Sheaffer *et al.,* (2000).

The highest leaf area index (LAI) was noted for *Pennisetum purpureum* followed by *Panicum typhoides*, and *Sorghum almum* with a non-significant difference from each other. *Digitaria decumbense* and *Panicum maximum* were non-significant in LAI from each other. *Chloris gayana* and *Panicum coloratum* was lowest in LAI among the tested group. Differences in LAI of grasses are due to differences in leaf size, number and its attachment angle with tillers (Akmal *et al*., 2010). Different grasses have different leaf size and its attachments with stem and hence showed variation in leaf area index. Leaf angle of attachment to tiller of grass is important for its surface exposure on ground and solar radiation interception during growth and development. It, therefore, has a significant effect on radiation use efficiency. Radiation use efficiency (RUE) was therefore found different with the highest for *Setaria anceps,* followed by *Panicum typhoides* and *Sorghum almum.* The lowest RUE was observed for *Digitaria decumbense.* The grass RUE is one of the most important parameter (Kiniry *et al*., 1989; Akmal *et al*., 2010). Due to population growth, land for future cultivation is limiting. The identification of efficient resource capturing grasses perform well under the drought may not only provide sufficient fodder but also work as resource capturing species that is capable to convert solar energy into biomass and hence could be used as source of animals' feeding. The different grasses were found different in RUE (Kiniry *et al*., 1999). The grasses have shown higher crop growth rate, leaf fraction in dry matter and relatively tall tillers can termed as efficient resource capturing grass due to their higher RUE values and hence resulted in higher dry matter.

Crop growth: Periodic dry matter increment of the different grasses is shown in Fig. 1. It was observed that different grasses respond differently under uniform inputs and similar environment. Differences in the upper asymptotic regions of grasses let us know its optimum time of defoliated in the area for higher biomass production. The early stage of maximum dry matter of a grass reached may allow its harvest early for fodder conservation. Additionally, the longer linear growth phase of a grass may lead it to contribute in eco-volume through canopy development (Carton *et al*., 2002; Slafer *et al*., 2009). It is due to that growth at linear phase is usually constant and species contributes in DM production. Such grasses can be classified as efficient resource capturing (Asim, 2010). Difference in linear growth phase of the different grasses can be correlated with canopy height, growth habit, and leaf senescence process to manage its defoliation accordingly. The slow growing response of the grasses e.g., *D. decumbense* and *D. swazilandensis* showed that such grasses have contributed more horizontally than vertically (Fig. 1). Their plant height is also reported the lowest among the group. Grass with relatively constant upwards growth curve (e.g., *S anceps, C. gayana and S. almum*) can effectively be harvested frequently during the active growing season and may provides relatively nutrition fodder with multiple cuts. Their higher RUE values showed that they have the potential to utilize the available resources for biomass production in the area. Such grasses could be termed as efficient resource capturing species for the area having sufficient poorly fertilized and wasteland.

Mean crop growth (CG), calculated as mean of dry matter (gm^{-2}) over time duration (days), is shown in Fig. 2. The figure revealed that grasses differed in CG between 60 to 100 days after re-generation. Inset box of the Fig. 2 shows relationship between observed and estimated dry matter of the grasses. Based on CG in relations to the growth curve, the grasses can be grouped in three categories. Grasses e.g. *S. anceps, P typhoides* and *S. almum* are the highest biomass producer with a relatively better and stable linear growth phase. The next relatively low yielding with almost similar growth response grasses are e.g. *C. gayana, P. purpurium, P. maximum, V. zizynoides* and *P. ccoloratum*. Grasses e.g. *D. decumbense* and *D. swazilandensis* were the slowest growing among the group. According to an estimate, more than 62% land is under Rangeland which is not fully covered with palatable grass species. A considerable portion of land in Pakistan is designated either uncultivated or cultural able wasteland and significantly contributes in environmental pollution. Species having potential to withstand drought and perform relatively good on marginal land with minimum nutrition can effectively be utilized for protection of land erosion, minimize environmental pollution and to some extent contribute is green fodder deficiency for the growing livestock number. Grasses e.g., *S. anceps, P typhoides* and *S. almum* has found efficient biomass producer under drought. Their propagation on cultureable waste land not only reduces the existing grazing pressure on rangeland but also contributes towards livestock performance. These grasses with sufficient nutrients and water may return quality fodder that could be conserved in mountainous region as winter fodder where fodder nutrition is very low (Akmal *et al*., 2010). The study suggests that different grasses differ in crop growth and biomass production. However, based on CG there are some potential species that could be effectively cultivated on wasteland to protect environment and made available some green fodder in areas which has sufficient barren land.

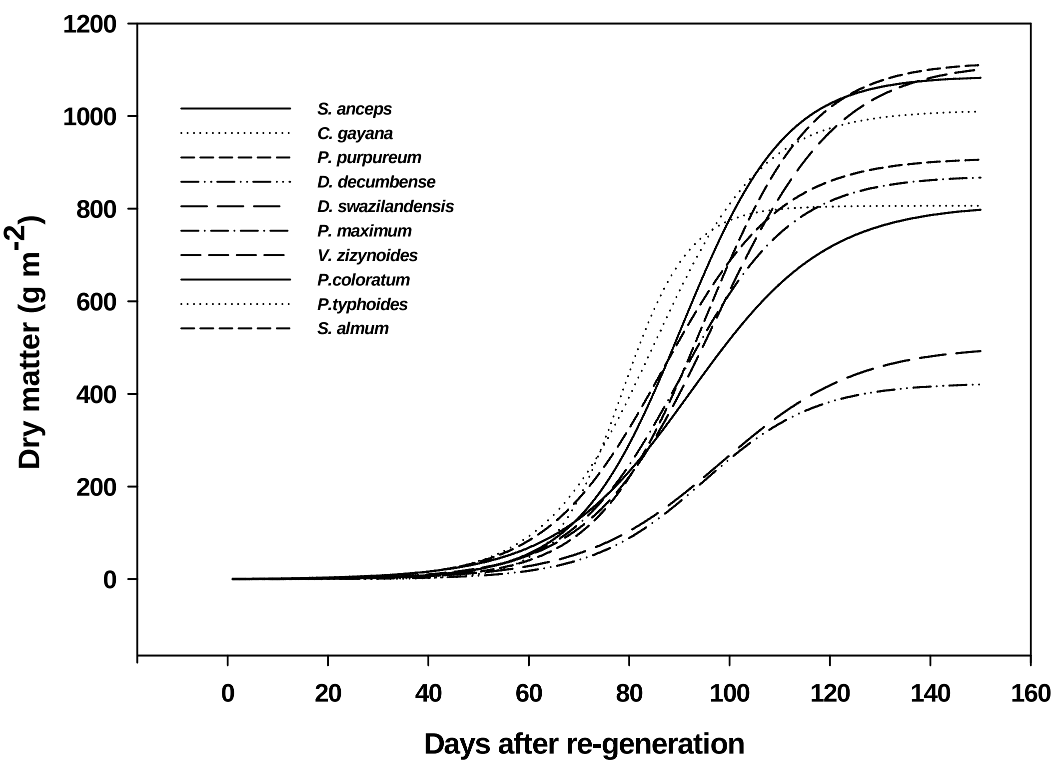

Fig. 1. Relationship of dry matter increment with days after re-generation for different perennial grasses grown as fodder.

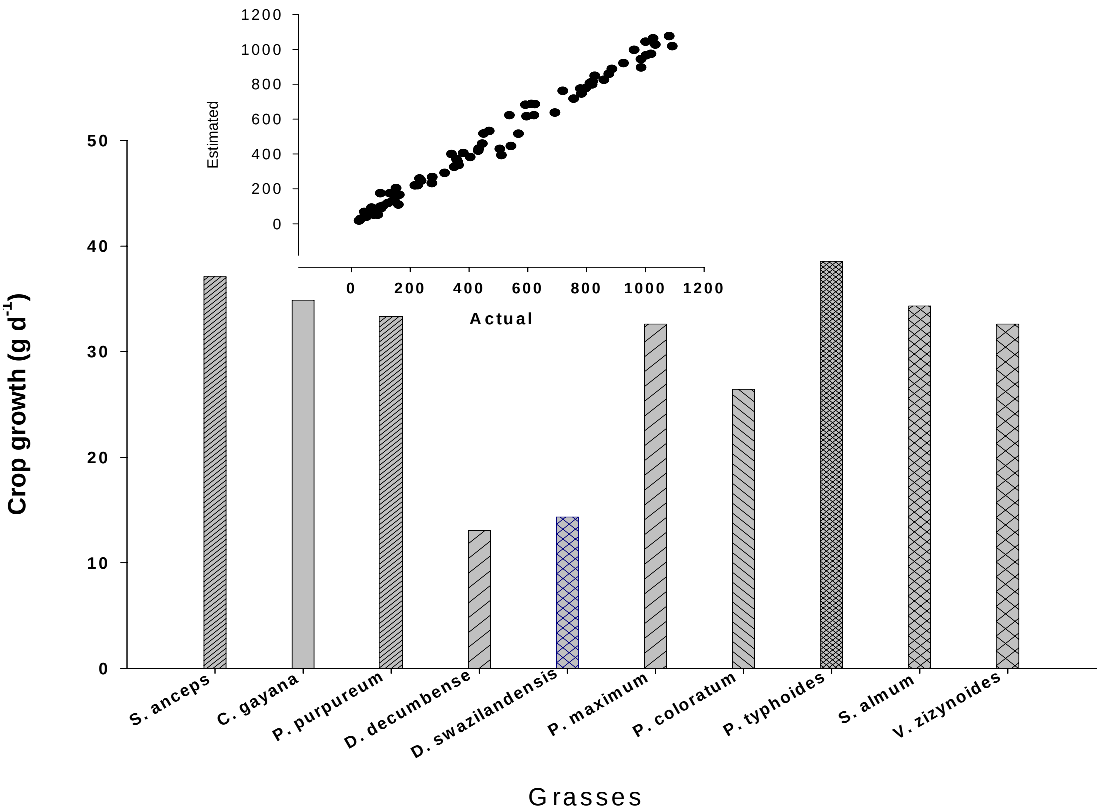

Fig. 2. Mean crop growth rate (CG) of the different grasses during early summer grown as fodder. Inset figure shows a strong positive relationship between the periodic actual and simulated dry matter data.

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