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GROWTH COMPARISON OF EXOTIC SPECIES FOR GREEN FORAGE

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Abstract

Growth of exotic fodder crops (grasses and clovers) were compared in pots at Agronomy Research Farm, Khyber Pakhtunkhuwa Agricultural University, Peshawar. Initially 20 seeds was planted on 22.10.2005 and thinned out after emergence by leaving 10 seedlings pot^{-1} (30 x 50 cm). Clover's seeds were soaked overnight (>14 h) before sowing. Compound fertilizer (100, 60, 30) and (30, 60, 30) kg ha^{-1} N, P, and K were applied to grasses and clovers, respectively after thinning. Pots were manually irrigated. Biomass of pots was periodically harvested for dry matter after taking measurements of green leaf area index (GLAI) and light interception. Crop growth rate (CGR) was derived as ratio of dry matter and time-taken as growing degree days (GDD ^{O}C). LAI was measured non-destructively using LI-2000, LI-COR, USA. Radiation use efficiency (RUE) was derived from weather data and measurements made during the crop growth. The highest dry matter (1685 g m^{-2}) was observed for *Lolium multiflorum*, followed by *Lolium perenne* (791 g m^{-2}) and *Dactylis glomerata* (631 g m^{-2}). GLAI were also recorded the highest for the species *Lolium multiflorum* (4.07) and *Lolium perenne* (3.93) with non-significant difference from each other. The highest dry matter of the grasses was in agreement to higher CGR and RUE. Grass species *Lolium multiflorum* yielded the highest CGR (1.06 g DM ^{O}C GDD) and RUE (3.41 g DM MJ^{-1} PAR absorbed) with strong positive relationship (r^2 = 0.95). *Lolium perenne* was next to yield 0.47 g DM GDD^{-1} (^{O}C) and RUE 1.63 g DM MJ^{-1} PAR absorbed. Rests of the grass species were found un-comparable for any observed parameter. Among the clovers, *Trifolium repense* was higher in dry matter (510 g m^{-2}) yielded 1.10 g DM GDD^{-1} and RUE 0.71 g DM MJ^{-1} PAR absorption. From the study, it can be concluded that ryegrasses has potential to plant as green fodder in mix cultivation with local clovers on irrigated rangelands. Moreover, slow growth of fodder on arable land in early winter months can be improved through selection of an appropriate exotic grass/clover to be sown in combination with local types for the area.

Introduction

Suitability and production of fodder species are depending on climate and soil of the region. Pakistan has opportunity of four seasons: cool, dry winter (Dec. to Feb.), hot dry spring (Mar. to May), rainy/monsoon summer (Jun. to Sep.) and re-treating monsoon (Oct. to Nov.) with diversified onset and duration within the seasons. The country is mostly arid having hot summer and cool or cold winter. About 75% mean annual rainfall occurs in Jul. – Sep. (monsoonal origin). It has been estimated that 69% area receive rainfall >254 mm, 22.2% between 254-508 mm, 5.4% between 508-762 mm and about 3.7% <762 mm. The average climate of the area is from arid to semi-arid (Branzon, 2007). Of the total area, 22.12 m ha i.e. 27.8% is cultivated. Grazing area accounts 49 million i.e., in Punjab (40%), Sindh (55%), KP (60%) and Balochistan (79%). However, fodder crops are grown on 2.36 m ha (12% of the cropped area) which hardly enough to fill rumen of the animal population (Khan *et al*., 2006). Area under fodder cultivation is shrinking with introduction and cultivation of new oil seed crops, vegetables and fruits (Anon., 2008). Shortage of fodder is prime factor affecting livestock performance. Acute shortage of green fodder observed in May-Jun (high temperature and low precipitations) and in Dec. - Jan. (low growth temperature). Total Digestible Nutrients (TDN) is also deficient of about 27.29 m t and digestible protein about 1.68 m t.

Livestock plays important role in country's economy. Livestock contribution in GDP of Agriculture sectors is 54% (Anon., 2008) but fodder has remained unproductive components of Agriculture policies. Two types of livestock production practices prevail; (a) the rural household where animals are closely integrated in rural subsistence economy using grown fodder and crop residue for feeding and (b) large herds kept in rangelands. Except in peri-urban and commercial rural farming systems, most of the herds are under nourished, under productive and present low fertility. Understanding and managing forage diversity is essential for development of livestock production in Pakistan in general and in KP in particular. Present fodder production is based on 7 major species e.g. sorghum, maize, millet, berseem, oat, mustard and guar (*Cyamopsis teragonoloba*). Summer fodder crops are primarily sorghum (*Sorghum bicolour*), maize (*Zea mays*), and millet (*Pennisetum americanum*). Other species are Sudan, Napier, sorghum-Sudan hybrid, cowpeas (*Vigna unguiculata*) Moth (*Vigna aconitifolia*) and jantar (*Sesbania grandiflora*). Summer fodders are mainly cereals with fractional contrivbution of guar a hardy spring leguminous that can tolerate drought and salinity. *Trifolium alexandrinum*, oats (*Avena sativa*), and mustard are major winter species. Shaftal (*Trifolium resupinatum*), lucerne (*Medicago sativa*), vetch (*Vicia* species) and barley (*Hordeum vulgare*) are rabi fodder crops. But yield of all fodder crops is low. Despite climatic conditions found conducive supplying round the year green fodder.

Light, major factor of production, is available in abundance free of cost in Pakistan. To overcome on existing dry matter deficiency in the country, freely available rangelands (ca. 68%) could be planted and/or rehabilitated with exotic potential grasses and legumes that could perform relatively better under soil and climatic conditions of the area. This study aimed to identify exotic fodder potentials in the area that yields nutritious green fodder.

Materials and Methods

Experimental setup: To study survival, growth rate, biomass production and light use efficiency, the experiment was conducted in pots under outdoor condition at Agricultural University Peshawar. Treatments were arranged in complete randomized design (CRD) replicated three times for each experimental unit. Sowing was done in pots due to limited seed of the fodder species obtained from Institute of Agronomy and Natural Resource Conservation, University of Bonn, Germany. Sowing was done on October 22, 2005 in locally prepared mud pots (30 cm d x 50 cm h) by planting 20 seeds of each grass and clovers and thinned out be leaving 10 seedlings pot^{-1} after emergence. Before sowing, the clovers seeds were soaked in water for a night (14 h) and inoculated with appropriate bacteria received along with seeds. In order to get uniform canopy structure, all pots were arranged together. To avoid border effect, extra rows of pots were provided to protect the experimental units. Weeding was manually performed on weekly basis to remove all weeds from pots. Each species (treatment) was planted in 24 pots. After emergence, fertilizer was applied at the rate of 100, 60 and 30 (kg ha^{-1}) to grasses and 30, 60 and 30 (kg ha^{-1}) to legumes. Required quantity of the nutrients for each pot was calculated on soil volume basis through pre determined established relationship using soil bulk density and pot volume. To ensure uniform distribution of the nutrients, fertilizer was applied in the solution form to all pots. Measured quantities of fertilizer were dissolved in known quantity of water and applied to each pot in calculated amount. Each pot received 100 ml solution once after emergence on Nov. 12, 2005. Pots were irrigated on alternate days from emergence till the final harvest. Periodic samplings were made by harvesting three pots randomly selected representing three replications for a treatment on determined dates. Detail about seed source, variety name and species are provided in Table 1.

Data and sampling procedure: Data were recorded during vegetative growth by harvesting three pots on each sampling date representing three replicates of the treatment. In grasses, seven periodic harvests at monthly intervals were exercised from Oct. 2005 to April 2006. In clovers, maximum four harvests were observed during growth and development due to slow growth of grasses in the initial establishment phase. It is to point out that each periodic sample harvested during vegetative growth were from different pots, however, representing uniform biomass. A randomly selected pot was used for Green Leaf Area Index (GLAI) and other supported data on each date and time. GLAI was recorded using nondestructive sampling machine (LI-2000, LI-COR, USA). The instrument was calibrated recording one above and three below readings in a pot canopy for single mean value. The GLAI reading was immediately stored and transferred to computer. The instantaneous light measurements in pot canopy were also recorded using quantum point sensor (Skye PAR Special, ELE UK). On sampling day, sensor was placed above, below and at inverted positions over the pot canopy to record irradiance, reflectance, and transmittance. Ten stable readings on each sampling were used to calculate mean irradiance, reflectance and transmittance for the canopy. Percent absorption of photosynthetically active radiations ($PAR_{\%}$) was derived using the following equation.

$$PAR_{\%} = (\text{Irradiance} - \text{Reflectance} - \text{Transmittance}) / \text{Irradiance} * 100$$

Daily global solar radiation data was taken from auto recorded weather station of Institute of Biology and Genetic Engineering (IBGE), KP AUP located at less than 100 m distance from the experimental site. The mean daily solar radiation data was multiplied with factor (0.47) to yield PAR (McCree, 1972). The derived PAR from emergence to final harvest date of experiment was accumulated to have accumulative PAR. The accumulative PAR reading was multiplied with corresponding $PAR_{\%}$ recorded on the sampling date to have cumulative PAR absorption ($CUMPAR_{abs}$). A simple regression was derived for $CUMPAR_{abs}$ and plant dry matter (DM) recorded on different dates for a species and slope of the regression is taken as Radiation Use Efficiency (RUE). Pots, already selected for GLAI and light measurements, were immediately harvested for fresh and dry matter determination. All harvested fresh matter of a pot was separately dried in oven at $70^{O}C$ for not less than 72 h. The pot biomass data was converted to g m^{-2} through pot surface area. Growing degree days (GDD) were also computed as average of the temperature from emergence to corresponding sampling till the final harvest by subtracting $6^{O}C$ as base temperature for grass and $10^{O}C$ as base temperature for clovers (Russels *et al*., 1984).

$$GDD = (\text{Temperature}_{Max} - \text{Temperature}_{Min}) \div 2 - (\text{Base temperature})$$

Dry matter as dependent factor was regressed with GDD as independent factor using the following Richards' nonlinear equation (Richards, 1959).

$$Y = a / (1 + b*Exp(-c*x))$$

Leaf and stem fraction were also recorded on selected samplings for species. Random sample was taken from dry matter at harvest and leaves were detached by leaving sheath with stem. Both leaf and stem parts were separately weighed and their fractions on percent basis were computed for the samples. Leaf to stem ratio (LSR) was determined. Crop growth rate (CGR) was calculated as difference in dry matters of 2 consecutive samples. All values of CGR of a species were averaged for single mean value. Data of experiments for grass and clovers were separately analyzed using appropriate design under SAS statistical programmed (SAS, 2000). Means were separated using least significance difference (LSD) test at 5% probability.

Results

Crop dry matter increments against time scale for exotic grass species during vegetative growth period is shown in Fig. 1. Difference in growth of the species with similar climate and inputs reveled variations do exist among the species. Dry matter increments against GDD reveal that growth progressed at emergence even though temperatures falls from sowing till the end of January. It was noticed that grasses e.g. *Lolium perenne*, *Lolium multiflorum*, *Festuca pretense* and *Festuca rubra* were able to show relatively better sigmoid curves for the study period. Other species e.g. *Poa pratense*, *Phleum pratense*, *Dactylis glomerata* were found relatively dormant in the early winter months with almost little growth at initial 1000 GDD. These species were observed relatively winter dormant and can performed better in spring for green fodder in the area. Data regarding final harvest yield of fresh and dry matter of the grass was found significant (Table 2). Among the grasses, *Lolium multiflorum* was observed the highest ($p<0.05$) in fresh matter production (5424 g m^{-2}). *Lolium perenne* was next high yielding species with about 2631 g m^{-2} fresh matter production. *Dactylis glomerata* could be rank 3^{rd} with significant ($p<0.05$) differences then *L. perenne*, followed by *Phleum pretense* yielding 1792 g m^{-2} fresh matter. The rest species were lowest with non-significant differences from each other. Dry matter yield of the exotic species were also found different with highest (1685 g m^{-2}) for *Lolium multiflorum* followed by *Lolium perenne* (791 g m^{-2}). *Dactylis glomerata* and *Phleum pretense* were non-significant in dry matter from each other. The lowest dry matter (422 g m^{-2}) yield was observed for *Festuca rubra*.

Table 1. Fodder species (grasses & clovers) studied for growth and survival at KP AUP during the crop growth season 2005-2006.

Species	Botanical name	Common name
Grass	*Lolium perenne* (L.)	Perennial ryegrass
Grass	*Festuca pratensis* (Huds.)	Meadow fescue
Grass	*Phleum pretense* (L.)	Timothy
Grass	*Festuca rubra* (L.)	Red fescue
Grass	*Dactylis glomerat* (L.)	Cocksfoot
Grass	*Lolium multiflorum* (Lam.)	Italian ryegrass
Grass	*Poa pretense* (L.)	Kentucky bluegrass
Clover	*Trifolium repense* (L.)	Ladino/White clover
Clover	*Medicago varia* (L.)	Lucerne (alfalfa)
Clover	*Trifolium hybridum* (L.)	Alsike clover
Clover	*Medicago sativa* (L.)	Lucerne (alfalfa)

Table 2. Exotic grasses mean fresh matter (FM), dry matter (DM), green leaf area index (GLAI), leaf fraction (%), stem fraction (%) and leaf to stem ratio (LSR) at KP AUP.

Grass species	FM(g m^{-2})	DM(g m^{-2})	LAI	Leaf (%)	Stem (%)	LSR
Lolium perenne	2631 b	791 b	3.93 a	63.0 c	37.0 a	1.70 b
Poa pratensis	1030 e	502 d	3.25 c	74.0 a	26.0 c	2.97 a
Festuca pratense	1105 e	517 d	3.84 b	65.3 bc	34.7 ab	1.93 b
Phleum pratense	1792 d	644 c	3.16 c	69.3 ab	30.7 bc	2.26 b
Festuca rubra	1071 e	422 e	2.90 e	68.3 bc	31.7 ab	2.16 b
Dactylis glomerata	2121 c	631 c	3.05 d	67.3 bc	32.7 ab	2.06 b
Lolium multiflorum	5424 a	1685 a	4.07 a	67.7 bc	32.3 ab	2.09 b

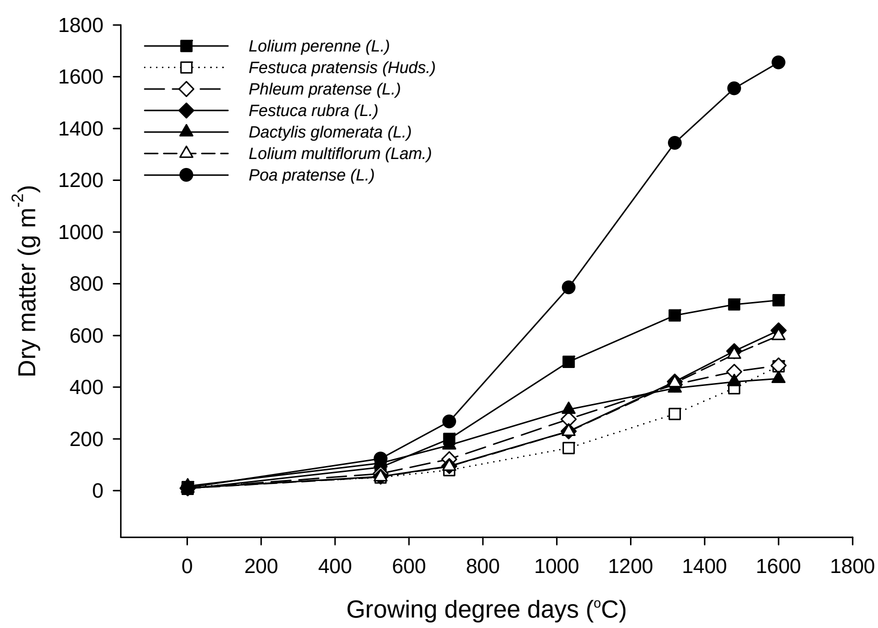

Fig. 1. Dry matter (g m^{-2}) production in relation to growing degree days (GDD ^{O}C) of different forage grasses at Peshawar, Pakistan.

Analysis of variance revealed significant differences in GLAI. The highest GLAI (4.07) was recorded for *Lolium multiflorum* due to its relatively broader leaves but did not differ ($p<0.05$) then *Lolium Perenne* (3.93). GLAI of *Festuca pratensis* was about 3.84 but lower from *Lolium perenne* ($p<0.05$). Rest of the species were different ($p<0.05$) in GLAI from each other with lowest (2.90) for *Festuca rubra*. GLAI increased against time (GDD) for all the species but with a different fashion (data not shown). All grasses shows relatively stable increase in GLAI when growth exceeds 500 GDD onwards. *Festuca rubra* was relatively slow in GLAI compare to other species of the experiment. Analysis of data revealed that different grasses showed different leaf and stem percentages with a significant ($p<0.05$) variations from one another. Among the grasses, *Poa pratensis* showed highest 74% leaf fraction in biomass production which did not differ than *Phleum pretense* (69.3%). *Festuca rubra* was next yielding 68% leaves in biomass followed by *F. rubra* (68.3%) and *D. glomerata* (67.3%). The lowest leaf fraction (63%) was observed for *Lolium perenne*. Stem fraction in biomass is opposite of that reported for leaf matters. Species yielded the highest leaf matter showed the lowest stem fraction and vice versa. Stem fraction of biomass was observed about one third of the total biomass of grass with highest (37%) for *Loilum perenne* and the lowest (26%) for *P. pratense.* For fodder crops, leaf to stem ratio (LSR) is interesting parameter to know the digestibility and intake efficiency of a species. The data reveals that grasses differed in LSR with highest (2.97) for *P. pratensis* that different ($p<0.05$) from rest of the species. All other species were non-significant ($p<0.05$) for LSR from one another.

Crop growth rate (CGR) i.e., g DM per unit GDD, the cumulative mean is shown in Table 3. Two different CGRs, derived from measured and estimated values (smoothing DM with Richard's equation) are shown in two separate columns. Both CGR values i.e., from the actual and estimated data were in agreement with each other for a species. It was observed that *L. multiflorum* was highest in yielding 1.22 and 1.06 g DM per unit changes in GDD. Crop growth rate of *L. perenne* was next (0.81 to 0.47 g DM), followed by *D. glomerata* (0.57 to 0.41 g DM). The lowest CGR (0.34 to 0.21 g DM) was observed for *F. rubra*. Crop growth values of the species were observed almost similar to that of DM reported in Table 2. Radiation use efficiency (RUE), the relationship of DM (g) a cumulative photosynthetically active radiation (PAR) MJ^{-1} absorbed, was derived from slope of the regression with r^2 values (Table 3). Radiation use efficiency was found linear for all grasses (r^2>0.90). *L. multiflorum* showed the highest RUE (3.41 g DM MJ^{-1} PAR absorbed), followed by *L. perenne* (1.63 g DM MJ^{-1} PAR absorbed). *P. pretense* was next high yielding RUE (1.35 g DM MJ^{-1} PAR absorbed). *P. pretense* was the lowest yield RUE 0.94 g DM MJ^{-1} PAR absorption.

Clover as fodder were separately analyzed and compared for growth. Data regarding branch number (BN) per plant, fresh matter (FM) and dry matter (DM) yield, leaf area index (GLAI) percent light absorbed (PLA) and leaf to stem ratio is shown in Table 4. The analysis of variance revealed that clover species found different in branch number per plant. From mean data, the highest branches per plant (15) were recorded for *Trifolium repense* which were almost similar to that of *S*-2000 (*Alfalfa*). The minimum branches per plant (12) were observed for *M. varia* which did not differ from *Trifolium hybridum* (13). *Trifolium repense* produced the highest FM (1943 g m^{-2}) compared to other species of the experiment, followed by *M. varia* (1391 g m^{-2}) and *Trifolium hybridum* (1243 g m^{-2}). *S-2000 was lowest in FM* (858 g m^{-2}) production. DM of clovers was also significant among the species. The maximum DM (510, 503 g m^{-2}) was recorded for *Trifolium repense* and *M. varia*, respectively. The lowest DM (338 g m^{-2}) was observed for *S*-2000 (*Alfalfa*). Among the clovers, maximum LAI (3.1) was recorded for *Trifolium hybridum* which did not differ then *M. varia* and *S*-2000 (*Alfalfa*). The minimum LAI 2.7 was observed for *Trifolium repense*. The percentage fraction of solar light absorption was recorded highest for *Trifolium repense* (83%) and the minimum (71%) for *S*-2000 (*Alfalfa*). The percent absorption of light recorded for the rest of the two species i.e., *M. varia* and *Trifolium hybridum* was 78.2% and 75.2%, respectively which did not differ from each other. Among clovers, the highest LSR was recorded for *Trifolium repense* (0.68). Rest of the species i.e., *Trifolium hybridum (0.56), S-2000* (0.54) and *M. varia* (0.52) were not significant from each other in LSR.

Data regarding crop growth rate and radiation use efficiency of the exotic clovers are shown in Table 5. Mean difference in DM revealed that *Trifolium repense* was the highest in yielding CGR of 1.10 g DM per unit change in GDD, followed by *Trifolium hybridum* with 0.87 g DM. Alfalfa (*S-2000)* was next yielding 0.84 g DM GDD^{-1}. The minimum CGR (0.74 g DM) was recorded for *M. varia* clover. Radiation use efficiency (RUE), slopes of regression for DM and cumulative PAR absorbed, is shown in Table 5 with r^2 values. Relationship of DM and cumulative MJ^{-1} PAR absorbed i.e., RUE was found linear with strong positive correlation (r^2 > 0.90) for all clovers. *T. repense* showed the highest RUE (0.71 g DM MJ^{-1} PAR absorption), followed by *M. varia (*0.70 g DM MJ^{-1} PAR). *T. hybridum* was next with 0.69 g DM MJ^{-1} PAR absorption. *S-2000* was the lowest in RUE (0.59 g DM MJ^{-1} PAR absorption).

Discussion

In this study, as expected, grasses have shown different growth than legumes in yield and dry matter production (Gillet, 1970; Langer, 1979; Albert and Kretschmer, 1978). We, therefore, analyze data of grass and clovers separately for comparison. Significant differences did exist for fresh and dry matter as well as CGR of grasses and clovers. Among grasses, *L. multiflorum* was high yielding of FM and DM. This high biomass corresponds to high leaf and stem fractions of the species. The highest DM of *L. multiflorum* was in agreement with highest CGR and RUE. It is an establish fact that leafy vegetation species allows higher interception of solar radiation (Akmal & Janssens, 2004). Therefore, high CGR of the species allows it to accumulate high DM with relatively efficient utilization of resources i.e., water and light (Long *et al*., 2005). The higher leaf area development of the species having all other factors e.g., pot size, soil type, nutrients and growth conditions uniform, were advantageous to yield high biomass under the climatic conditions. Such species could be classified as efficient in resource capturing to plant as potential forage in the area. It is known that rapid leaf area development enables species to accumulated matter faster and can be harvest relatively frequently for maximum utilization of the natural resources e.g., solar light, CO_2 and precipitation. Though not all but less than 50% of light is required for photosynthesis and the rest 50% is near infrared (> 700 nm) whose energy of photons is too low to drive charge separation at photosynthetic reaction. It is known that crop canopy architecture provides better distribution of light through maintaining high efficiency for photosynthesis under the light-limiting conditions (Long *et al*., 2005). Leaf photosynthesis responds non-linearly with increasing solar energy because of saturation of photosynthetic photon flux densities (PPFD). It is known that about one-quarter of maximum full sunlight received to crop canopy and any further PPFD intercepted above the optimum is generally wasted (Long *et al*., 2005). Critical leaf area index (CLAI) is reported three for grasses (Akmal, 1997) and a mature, healthy crop has usually three or more layers of leaves. Leaf of plants with horizontal arrangements showed higher intercepts at top that declines towards bottom and hence results slow growth with high stem fraction. Grasses and clovers as forage with high CGR and RUE can defoliate frequently for high biomass and relatively high forage quality (Iqtidar & Durrani, 1989; Krzywiecki *et al*., 1984). It is known that when plant grows its biomass almost leafy, thereafter, stem formation starts late and increased with high rate (Gregory *et al*., 1992). The crop LSR usually decreases with advancement in growth and is the most interesting factor to be examined for quality aspect of the forage species (Tofinga *et al*., 1993). The trend of decrease in LSR could be an indicator of fodder selection while leaf is three time high in %N than stem (Akmal, 1997). Legumes, contrary to grass, have shown similar growth trend. The higher branches number of the legume resulted denser canopy and allowed higher light interception that resulted high biomass.

It is concluded that exotic grasses and legumes do have great potential yielding green fodder under the climatic conditions of Peshawar. Ryegrass has relatively high resistance to yield fodder under low temperature of the early winter months. Some have relatively better yield performance when temperature is mild in spring. The grasses in combinations with local and/or exotic legumes can perform relatively good biomass on rangeland and arable lands in the area. Research on relatively larger area with appropriate seeding rates and mixtures in combinations needs to be carried out to overcome green fodder deficiency with higher total digestible nutrients for improving animal performance over the traditional forage production system.

Table 3. Exotic grasses mean crop growth rate (CGR) derived from actual (A) and estimated (E) data and radiation use efficiency (RUE) at KP AUP.

Grass species	CGR (A) g DM GDD^{-1} (^{o} C)	CGR (E) G DM GDD^{-1} (^{o} C)	RUE G DM MJ^{-1} PAR
Lolium perenne	0.81(±0.14)	0.47 (±0.04)	1.63 (r^2=0.90)
Poa pratensis	0.47 (±0.05)	0.35 (±0.04)	0.94 (r^2=0.99)
Festuca pratensis	0.52 (±0.06)	0.31 (±0.02)	1.04 (r^2=0.92)
Phleum pratense	0.56 (±0.04)	0.43 (±0.04)	1.35 (r^2=0.98)
Festuca rubra	0.34 (±0.05)	0.27 (±0.02)	0.97 (r^2=0.94)
Dactylis glomerata	0.57 (±0.04)	0.41 (±0.03)	1.27 (r^2=0.99)
Lolium multiflorum	1.22 (±0.08)	1.06 (±0.08)	3.41 (r^2=0.95)

Values in parenthesis show mean standard errors and correlations of the regression equations

Table 4. Exotic legumes branch number (BN), fresh matter (FM), dry matter (DM), green leaf area index (GLAI), percent light absorbed (PLA) and leaf to stem ratio (LSR) at KP AUP.

Clovers	BN	FM (g m^{-2})	DM (g m^{-2})	LAI	PLA	LSR
Trifolium repense	15 a	1943 a	510 a	2.7 b	82.7 a	0.68 a
Medicago varia	12 a	1391 b	503 a	3.0 ab	78.2 b	0.52 b
Trifolium hybridum	13 b	1243 c	438 b	3.1 a	75.2 b	0.56 b
S-2000 (Alfalfa)	14 ab	858 d	338 c	3.0 ab	71.0 c	0.54 b

Table 5. Exotic legumes mean crop growth rate (CGR) derived from periodic data and radiation use efficiency (RUE) observed during the experiment at KP AUP.

Legume species	CGR g DM GDD^{-1} (^{o} C)	RUE g DM MJ^{-1} PAR
Trifolium repense	1.10 (±0.19)	0.71 (r^2 = 0.96)
Medicago varia	0.74 (±0.04)	0.70 (r^2 = 0.97)
Trifolium hybridum	0.87 (±0.23)	0.69 (r^2 = 0.97)
S-2000 (Alfalfa)	0.84 (±0.24)	0.59 (r^2 = 0.90)

References

Akmal, M. and M.J.J. Janssens. 2004. Productivity and light use efficiency of perennial ryegrass under contrasting water and N supplies. *Field Crops Res*., 88: 143-153.

Akmal. 1997. Growth of forage grasses under different nitrogen levels and water regimes. Dissertation submitted to Faculty of Agriculture. University Bonn, Germany.

Albert, E. and J.R. Kretschmer. 1978. Productivity of rye grass (*Lolium multiflorum* Lam) and berseem clover (*Trifolium alexandrinum* L). *Proc. Soil and Crop Sci. Soc. of Florida*, 37: 30-34. Abstract. ASA: 35-46.

Anonymous. 2008. MINFAL. Agriculture Statistics of Pakistan. A hand book issued by the Ministry of Food and Agriculture, Government of Pakistan.

Brunzon V. 2007. Feed and Fodder mission report from April 4 to 27, 2007. A report submitted to Strengthening of livestock services project, financing agreement number PAK/RELEX/2001/0129 by Agrotec.

Gillet, M. 1970. Some aspects of the growth and development of the entire grass plant in natural conditions. *Festuca pratensis* Huds. Agron. J., 80: 188-190.

Gregory, P.J., D. Tennant and R.K. Belford. 1992. Root and shoot growth, and water and light use efficiency of barley and wheat crops grown on a shallow duplex soil in a Mediterranean type environment. *Aust. Agric. J*., 43: 555-573.

Iqtidar, A. K. and F. R. Durrani. 1989. Nutritional evaluation of tropical legume and cereal forages grown in Pakistan. *Tropical Agric. J*., 67: 313-315.

Khan S., M. Ashiq and M.B. Bhatti, 2006. Status of fodder in Pakistan. P. 11-24. In Fodder production in Pakistan. Pak. Agric. Res. Council. and FAO, Islamabad.

Langer, R.H.M. 1979. How Grasses grow, 2nd Ed. Edward-Arnold (Publishers) Ltd. London.

Long S.P., E.A. Ainsworth, A. Rogers, and D.R. Ort. 2005. Rising atmospheric carbon dioxide: plants face their futur. *Annual Review of Plant Biology*, 55: 591-628.

McCree, K.J. 1972. The action spectrum, absorption, and quantum yield of photosynthesis in crop plants. *Agron. J*., 9: 191-216.

Richards, F.J. 1959. A flexible growth functions for empirical use. *Experimental. Bot. J*., 10: 290-300.

Russels, M. P., W.W. Wilhelm, R.A. Olsonand and J.F. Power. 1984. Growth analysis based on degree days. *Crop Sci*., 24: 28-32.

Tofinga, M. P., R. Paolini, and R. Snaydon. 1993. A study of root and shoot interactions between cereals and peas in mixtures. *J. Agric. Sci. Camb*., 120: 13-24.

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