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CROP GROWTH IN EARLY SPRING AND RADIATION USE EFFICIENCY IN ALFALFA

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Abstract

The study was conducted at Agronomy Research Farm, KP Agricultural University Peshawar. Fifteen alfalfa lines (*M. sativa* L.) were compared for crop growth rate (CGR), biomass yield and radiation use efficiency (RUE). The previous year experiment was defoliated on 13th March 2006 at ground levels about 5 cm height. Fertilizer to the crop was applied every year in 1st week of March to yield 30, 60, & 30 kg ha^{-1} N, P, & K, respectively after defoliation. Periodic samples were harvested from one meter row length at two locations and oven dried at 70^{O}C for about 36 h. Before samples, periodic leaf area index (LAI) was recorded with LI-2000 (LI-COR, USA) and subsequently light measurements were made using data logger (LI-1400, LI-COR, USA) and light sensors LI-190 and LI-191 (LI-COR, USA). The CGR showed variation in shapes and asymptotes for the different alfalfa lines which resulted differences in both fresh and dry matters yield at final sampling harvest. Alfalfa line Gramma-2 was the highest in dry matter yield (110 g m^{-2}) followed by Flewish-pop (107 g m^{-2}). Alfalfa line Pumha with 74 g m^{-2} was the lowest in dry matter yield. Differences were observed in LAI ($p<0.05$). High dry matter yield of alfalfa line *Gramma-2* was due to higher LAI which was associated to highest leaf fraction (38%). Differences in RUE were also observed among the lines. *Flewish-pop* was the highest in RUE *(*0.20 g DM MJ^{-2} PAR absorbed), followed by *Gramma-2 (*0.18 g DM MJ^{-2} PAR absorbed). Mean CGR and RUE of the different lines showed association with dry matter yield of which the lateral one showed a strong association compared with the earlier one. We conclude that higher RUE than CGR is important for the line/variety to get quality fodder production.

Introduction

Livestock is important sector of Pakistan's economy. Agriculture contributes 23% in GDP and livestock share in the Agriculture DGP is about 49%. Fodder is prime sector of improvement of livestock in the country. However, green fodder is short in terms of dry matter and total digestible nutrients (Hatam *et al*., 2001). One reason of this shortage is little research on fodder production. Further to this livestock major dependency is cereal's straw, corn stalks, sorghum and millets. Fractions of sugarcane tops and beet-pulp also contribute as fodder. Green forage is mostly harvested from clovers where berseem and shaftal are the leading species (Dost, 1997) which are annual and planted in October to yield green fodder from January until May.

Wheat is major competitive with winter fodder species in the area. Contrary to that summer fodders are maize, sorghum and millets (all cereals) and contribute low (<8%) in the daily protein requirements as recommended (>10%). Shortage of green fodder is acute in June - July. and in November–December. Animal's performance in terms of higher efficiency in the country relates to green fodder availability and its quality (McIntyre, 1994). Reports revealed that country is short of more than 200 million tons of green fodder and 30 - 42% total digestible nutrients (Bhatti, 1996). Grass and clover are main fodder supply sources of livestock production in the country. Clovers always found higher in protein than grasses (Akmal, 1997) but grasses in comparison to the clovers are relatively stable under low temperature and contribute in swards production (Nemato *et al*., 1995; Wall *et al*., 2006). Clovers being important constituent of the grassland also contribute for N fixation and hence subsidized fertilizer cost in the production system. Moreover, clover with grass increases N-digestibility within the animal rumens by decreasing the release of indigestible ammonia. Clovers are rich forage source of N and show efficient growth under sufficient water availability (Akmal, 1997; Evers & Newman, 2008).

Ryegrass is important constituent of grassland due to resistant against cold (Akmal, 1997). However, clovers with grass combination can reduce risk of weed infestation, bloating and increase canopy growth and development. Adaptation of new species mostly brings change in the production. Solar radiation is main energy contributing in production through photosynthesis (Teixeira *et al*., 2008) but efficient light conversion for high fodder is advantageous to contribute for yield. Greater surface area or canopy volume of a variety may contribute higher in resource capturing i.e. solar light and CO_2 resulting faster biomass production. Moreover, high leaf fraction results higher fodder quality with higher crude protein and digestibility (Akmal & Janssens, 2004). Light is the primary source of photosynthsis and higher production is subjected to the maximum light interception by the crop canopy (Brown *et al*., 2006). Light fraction advantageous to plants is called photosynthetically active radiation (Teixeira *et al*., 2008) and is directly proportional to the canopy volume. Light conversion to chemical energy depends on leaf area (Brown *et al*., 2006), rate of radiation interception and crop photosynthetic rate (Stewart *et al*., 2003).

Experiments have been conducted on light interception and radiation use efficiency of crops but little is known about alfalfa varieties/lines to compare for RUE (function of g DM MJ^{-1} PAR absorbed). RUE is an effective tool comparing the species for production. The study therefore aims to identify CGR and RUE relationship with productivity.

Materials and Methods

To compare crop growth and biomass of exotic alfalfa lines, the experiment was conducted at KP Agricultural University Peshawar. Fifteen lines of alfalfa were compared for CGR, dry matter yield and RUE. Sowing was done in October 2004 in rows (5 m length, 30 cm apart). Fresh and dry matter was measured in a seasonal cut. To comparison crop growth, herbage was uniformly harvested at 5cm height on March 17, 2006 and fertilizer was applied at the rate of 60, 100 and 30 kg ha^{-1} for N, P and K, respectively every year in the month of March. Weeding was done after each harvest. Field was irrigated as per crop water demand. Periodic samplings were made by harvesting one meter row in each experimental unit at two locations at 10-15 days interval. Total seven samples were harvested for the study between April and June, 2006 to compare CGR and RUE. Name of alfalfa lines with seed source of the study are shown in Table 1.

Data were recorded for fresh and dry matter from each cut usually harvested for fodder. For CGR and RUE, periodic samples were harvested at 10-15 days interval after provided a compete defoliation to the swards. Leaf area index (LAI) was measured using non-destructive LI-2000 machine (LI-COR, USA). All measurements were made on selected locations by placing sensor head above and below the canopy. Data were immediately stored in data logger and transferred to PC. Three readings per plot were recorded and averaged for a mean. Instantaneous light interceptions were recorded using quantum sensors LI-190 and LI-191 (LI-COR, USA) where LAI was recorded and dry matter harvested. On the measurement day, sensors were placed above, below and at inverted positions over the canopy to record irradiance (L_I), reflectance (L_R), and transmittance (L_T). Maximum ten instantaneous readings were stored for a treatment and averaged. Percent absorption of the photosynthetically active radiations (PAR) was derived as follows (Akmal and Janssens, 2004).

$$PAR_{(\%)} = [((L_I - L_R - L_T) / L_I) * 100]$$

Table 1. Names and source of seed collection of alfalfa lines compared for crop growth and light use efficiency at Agric. Univ. Peshawar.

S. No.	Lucerne lines	Origin	Seed supply source
1.	DRAQ-2	USA	Fodder Res. Institute, Sargodha
2.	Pumha	Argentina	Fodder Res. Institute, Sargodha
3.	1-250-78	Egypt	Fodder Res. Institute, Sargodha
4.	AK-3A	USA	Fodder Res. Institute, Sargodha
5.	E-542	Spain	Fodder Res. Institute, Sargodha
6.	CUF-101	FRI, S	Fodder Res. Institute, Sargodha
7.	Gramma-1	USA	Fodder Res. Institute, Sargodha
8.	K-1107	Jordan	Fodder Res. Institute, Sargodha
9.	Gramma-2	Canada	Fodder Res. Institute, Sargodha
10.	G-R-800	Morocco	Fodder Res. Institute, Sargodha
11.	Flewish-pop	USA	Fodder Res. Institute, Sargodha
12.	No-12-991	FRI, S	Fodder Res. Institute, Sargodha
13.	1-251-78	Egypt	Fodder Res. Institute, Sargodha
14.	W-268	USA	Fodder Res. Institute, Sargodha
15.	Brearer	USA	Fodder Res. Institute, Sargodha

Daily global solar radiation was taken from local weather station located at the Institute of Biology and Genetic Engineering (IBGE), Agric. Univ. Peshawar. PAR was derived from solar readings with multiplication by factor 0.47 (McCree, 1972). Cumulative PAR were taken from day of defoliation till the final sampling date and multiplied with $PAR_{(\%)}$ for each measured values of the samplings. RUE was calculated by regressing dry matter (g m^{-2}) and corresponding accumulative PAR (MJ m^{-2}). Slope of the regression equation is RUE (g DM MJ^{-1} PAR intercepted) for the alfalfa line. Data were analyzed adopting appropriate design and mean where found significant were separated through least significance difference ($p<0.05$).

Results and Discussion

Alfalfa due to its perennial nature is termed as queen of fodder yielding the highest green matter round the year. It grows well on both arable and rangelands having sufficient moisture at initial establishment stage. Thereafter, strong rooting system develops which enables its growth under drought and cold. In this study it was focused to compare alfalfa lines of early summer through CGR and RUE. The relationship of crop dry matter (dependent factor) and cumulative growing degree days (GDD = independent factor) is shown in Fig. 1. Growth performance of alfalfa lines revealed that *No 1-251-78* was the highest in dry matter yield followed by *AK-3A*, *Gramma-2*, and *Flewish-pop*. The crop growth rates of these lines were sigmoid with relatively efficient dry matter accumulation against change in GDD. Differences in dry matters accumulation of the alfalfa lines from each other during linear growth showed that lines do differ in biomass production.

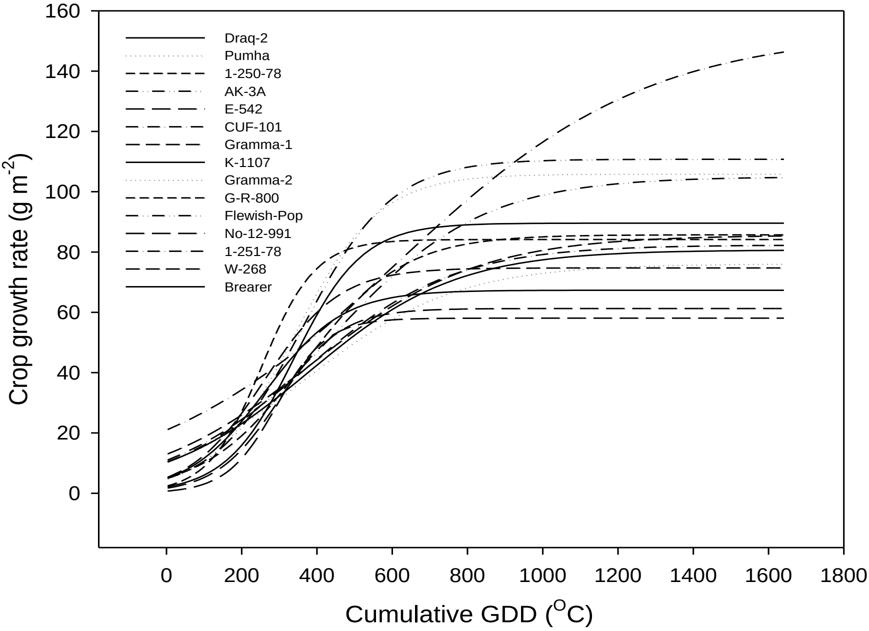

Fig. 1. Crop dry matter (g m^{-2}) in relation to cumulative growing degree days (^{O}C) of the different alfalfa lines in early summer in Peshawar.

Mean data for final cut indicated that alfalfa lines do diversified in the productivity under the climate provided with common inputs during growth (Table 2). Among all the lines, *I-251-78*, *G-R*-800, *Gramma*-2, and *Gramma-1*, produced the highest matters i.e. 353.99g, 352.94g, 338.57g, and 351.29g $m^{-2,}$ respectively. These lines were statistically non-significant from each other. Lines *K-1107*, *Draq-2*, E-542 and Pumha were next high yielding lines with fresh matter production of 321, 249, 242 and 236 g m^{-2} respectively. Dry matter yield of alfalfa lines showed that highest dry matter was observed for *Gramma-2* (110.0 g m^{-2}) with a non-significant difference for *Flewish-pop* (107.75 g m^{-2}), followed by *I-251-78* (103.75 g m^{-2}) and *AK-3A* (103.19 g m^{-2}). The lowest dry matter was reported for line *12-991*, *Draq-2*, and *E-542* yielding 68.57, 68.12, and 67.50 g m^{-2}, respectively. Plotting CGR and RUE of the lines against dry matter production, it was noticed that CGR and dry matter of these lines were in agreement (Fig. 2). Lines do vary in dry matter production but their CGR remains static. However, RUE with dry matter showed a linear positive relationship. Increase in dry matter resulted higher RUE. Therefore, increase in dry matter of a line is more corresponds to RUE and not to CGR. As expected, there were differences in fresh and dry matters of the different lines of alfalfa which may be due to water accumulated in plant organs (Gawali & Bhaskar, 1994: Brown *et al*., 2006). Although, there was differences in leaf to stem fractions and we knew that both organs accumulate different quantities of water (Brown *et al*., 2006). Therefore, different lines do have resulted different fresh and dry matters. The highest fresh matter may not results higher dry matter due to differences in leaf and stem fractional weights and their moisture contents (Akmal, 1997). Moreover, variation in leaf area index and leaf fraction may make difference in the available water content of the organs biomass of these lines and hence results different fresh and dry matters.

Table 2. Fresh matter (FM), dry matter (DM) and leaf area index (LAI) of alfalfa lines in spring 2006 at NWFP AUP.

Variety	FM ($g\ m^{-2}$)	DM ($g\ m^{-2}$)	LAI
Draq-2	249.37 e	68.12 h	3.10 c
Pumha	235.62 e	74.31 g	3.08 c
1-250-78	285.08 d	83.68 e	3.03 d
AK-3A	285.37 d	103.19 c	2.97 e
E-542	241.55 e	67.50 h	2.96 e
CUF-101	302.35 c	83.13 e	3.15 b
Gramma-1	352.94 a	86.02 de	3.23 a
K-1107	321.23 b	87.39 de	3.13 bc
Gramma-2	338.57 a	110.00 a	3.00 ed
G-R-800	351.29 a	90.14 d	3.01 ed
Flewish-pop	314.03 bc	107.75 ab	3.00 ed
No.12-991	305.65 bc	68.57 h	2.98 ed
1-251-78	353.99 a	103.75 bc	3.00 ed
W-268	285.94 d	78.57 fg	2.99 ed
Brearer	276.19 d	78.77 f	3.09 c

Means followed within a category with common letters are not significant ($P<0.05$) using LSD test.

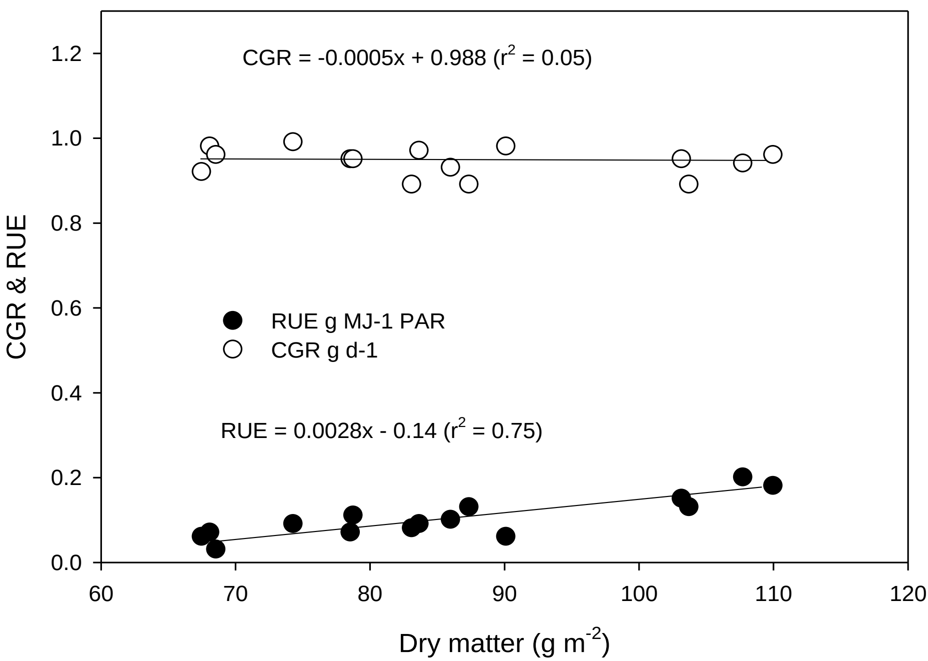

Fig. 2. Crop growth rate ($g\ d^{-1}$) and radiation use efficiency ($g\ DM\ MJ^{-1}\ PAR_{absorbed}$) in relation to dry matter production of different alfalfa lines in Peshawar.

Table 3. Leaf (LW%), stem (SW%) fraction, radiation use efficiency (RUE) and crop growth rate (CGR) of alfalfa lines in spring 2006 at NWFP AUP.

Variety	LW (%)	Stem (%)	RUE (DM g MJ^{-2})	CGR (g DM GDD^{-1})
Draq-2	36.20 a	63.79 ef	0.07 (r^2=0.97)	0.09 (± 0.02)
Pumha	24.18 ef	75.82 ab	0.09 (r^2=0.93)	0.09 (± 0.02)
1-250-78	26.18 def	73.81 abc	0.09 (r^2=0.99)	0.11 (± 0.02)
AK-3A	26.83 cdef	73.16 abcd	0.15 (r^2=0.97)	0.14 (± 0.02)
E-542	28.12 bcdef	71.87 abcde	0.06 (r^2=0.71)	0.09 (± 0.02)
CUF-101	40.91 a	59.08 f	0.08 (r^2=0.99)	0.12 (± 0.03)
Gramma-1	27.85 bcdef	72.15 abcde	0.10 (r^2=0.97)	0.11 (± 0.02)
K-1107	20.91 f	79.08 a	0.13 (r^2=0.88)	0.15 (± 0.03)
Gramma-2	37.98 a	62.01 f	0.18 (r^2=0.84)	0.14 (± 0.02)
G-R-800	24.97 def	75.03 abc	0.06 (r^2=0.54)	0.11 (± 0.03)
Flewish-pop	37.81 a	62.19 f	0.20 (r^2=0.91)	0.16 (± 0.03)
No.12-991	35.40 abc	64.59 def	0.03 (r^2=0.78)	0.10 (± 0.04)
1-251-78	32.48 abcde	67.51 bcdef	0.13 (r^2=0.84)	0.13 (± 0.03)
W-268	32.96 abcd	67.04 cdef	0.07 (r^2=0.86)	0.10 (± 0.02)
Brearer	39.99 a	60.00 f	0.11 (r^2=0.93)	0.01 (± 0.02)

Means followed within a category with common letters are not significant (P<0.05) using LSD test

Data regarding LAI of alfalfa lines are presented in Table 2. Analysis of variance revealed that significant differences (p<0.05) do exist in LAI. Mean data showed that the highest LAI (3.23) was recorded for *Gramma-1* followed by *CUF-101* (3.15) which did not differ from *K-1107* (3.13). The minimum LAI (2.97) was recorded for *AK-3A* and *E-542* (2.96). Leaf fraction of the different lines revealed (Table 3) that maximum leaf weight in dry matter was recorded for *Draq-2, CUF-101*, *Gramma-2, Flewish-pop* and *Brearer yielding* 36.20, 40.91, 37.98, 37.81, 39.99 g m^{-2}, respectively. All these lines for percent LW were non-significant (P<0.05) from each other. The lowest leaf weight (20.91%) was recorded for line *K-1107*. Different alfalfa lines also varied for stem with the highest (79.08%) for *K-1107*, followed by *pumha* (75.82) and the lowest (59.08%) for *CUF-101*. Differences in leaf area indices of the different verities and/or lines are common in species (Teixeira *et al*., 2007).

Radiation use efficiency (RUE) was found different for the different alfalfa lines. It was observed that alfalfa line *Flewish-pop was high resource capturing with* 0.20 g DM MJ^{-2} PAR absorbed among the other line when compared in the group. This followed by line *Gramma-2* with about 0.18 g DM MJ^{-2} PAR absorbed. The lowest RUE was recorded for *No. 12-991* which was about 0.03 g DM MJ^{-2} PAR absorbed. Differences in RUE within lines are due to their growth and assimilates partitioning and climate of the seasons (Brown *et al*., 2006). Crop growth, keeping all other factor constant, revealed that different lines were significantly different from each other (Table 3). The maximum CGR about 0.16 g DM GDD^{-1} was recorded for *Flewish-pop*, followed by *K-1107* (0.15 g DM GDD^{-1}). The lowest CGR about 0.01 g DM GDD^{-1} was observed for *Brearer*. High interception of solar radiation by the crop canopy results higher growth with higher accumulation of matters. Here all lines were of common species having different canopy architecture with clear differences in leaf attachments to stem and their inclination to the ground which might have caused differences in the interception of the solar radiations (Akmal & Janssens, 2004). Here one may conclude that higher the light interception of the canopy results higher growth and biomass production. Moreover, high crop growth rates may advantageous to reach canopy closure stage relatively faster through higher leaf area expansion in the initial stage of growth. This results maximum light interception to accumulate more assimilates as leaves and stems which results higher biomass for frequent defoliation in season. For green fodder, early canopy closure is therefore advantageous over other filed crops in agriculture.

Conclusion

Crop growth is function of dry matter production to build canopy volume. However, it is important to note the rate of development that contributed in leaf organs e.g. leaf and stem fractions. Higher stem fraction per unit canopy volume may increase in dry matter yield but may have an adverse effect on fodder quality due to higher fiber content and/or lignifications. Stem is reported higher in dry matter at late stage of development and has decreased fodder intake due to less digestibility and crude protein contents. The study suggests that higher CGR of a variety is important for high dry matter yield but higher RUE in relation to dry matter is advantageous for fodder quality.

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