

# GRAIN YIELD AND BIOMASS PRODUCTION OF THREE CULTIVARS OF *LUPINUS LUTEUS* WITH DIFFERENT CROP ARCHITECTURE

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## ABSTRACT

Grain yield is the consequence of biomass production and its partitioning. Crop architecture can affect both of them. The objective of this study was to evaluate the response of grain yield, above-ground biomass and biomass partitioning in three cultivars of *L. luteus* with different crop architecture: (i) Mielero (high basal branching); (ii) Yuno (high first order branching); and (iii) Legat (low branching) under field conditions. At harvest, grain yield, above-ground biomass and yield components were measured. Incident and transmitted radiation were measured and radiation use efficiency was calculated. Grain yield showed clear differences ( $p < 0.01$ ) among cultivars. Yuno reached the highest yield ( $643.2 \text{ g m}^{-2}$ ), Mielero the lowest ( $389.5 \text{ g m}^{-2}$ ) and Legat intermediate ( $442.7 \text{ g m}^{-2}$ ) values. Mielero showed lower harvest index (22%) than Yuno and Legat (33%). Yield was correlated with grain number. As cultivars showed similar ( $p > 0.10$ ) biomass at anthesis, differences found at maturity ( $p < 0.05$ ) were due to the post-anthesis growth ( $p < 0.01$ ). Similar values of RUE ( $p > 0.05$ ) were found at the pre-anthesis phase among cultivars (between  $1.7$  and  $1.9 \text{ g MJ}^{-1}$ ). Yuno showed the highest RUE both during the whole crop cycle ( $2.12 \text{ g MJ}^{-1}$ ) and at the post-anthesis phase ( $2.43 \text{ g MJ}^{-1}$ ).

## KEYWORDS

yield, yellow lupin, radiation use efficiency, canopy architecture

## INTRODUCTION

Grain yield is the consequence of biomass production and its partitioning to reproductive organs. In lupin, plant architecture can contribute to a higher and more stable grain yield by affecting biomass production and/or biomass allocation between vegetative and reproductive organs (Huyghe, 1998; Palta *et al.* 2008). The efficiency of lupin canopy to intercept radiation (RI) and using it in producing biomass (RUE) are the major physiological determinants of crop biomass. In addition, both RI and RUE are affected by plant architecture (Jeuffroy and

Ney, 1997). Regarding that plant architecture is a dynamic processes associated with crop development (Huyghe, 1998), both RI and RUE could be modified during the crop cycle with possible impact on grain yield (Cowling *et al.* 1998). Despite plant architecture is of central importance on the physiological determinants of biomass few studies have investigated the effect of this trait on RI and RUE in lupin during the entire crop cycle or at different phenological phases. For example, Ayaz *et al.* (2004) evaluated the effect of different seed rates on RI and RUE in four grain legumes (chickpea, lentil, narrow-leafed lupin and pea). These authors, in agreement with Supasilapa *et al.* (1992), found that both RI and RUE increased at increasing seed rate. Ayaz *et al.* (2004) hypothesised that higher RUE found at the highest seed rate was due to more erect leaves in dense canopies. Therefore, it could be expected that leaf angle and plant branching could modify light distribution within the canopy and consequently, RI and RUE of lupin crops. The present study was aimed at evaluating three yellow lupin cultivars with different branching patterns and biomass partitioning, and their effect on RI and RUE at pre- and post-anthesis.

## MATERIALS AND METHODS

### SITE AND CROP MANAGEMENT

A field experiment was conducted on a Typic Hapludand soil at the experimental station of Universidad Austral de Chile in Valdivia ( $39^{\circ} 38' \text{ S}$ ,  $73^{\circ} 5' \text{ O}$ , 19 m above sea level), Chile. Three yellow lupin cultivars (Mielero, Yuno and Legat) were sown by hand on 4 September of 2006. These cultivars were chosen taking into account differences in plant architecture and biomass partitioning. Cultivars were Mielero, which is a cultivated ecotype with high basal branching, indeterminate habit and low harvest index (HI), while the other two cultivars (Yuno and Legat) have higher HI. Yuno is a high first order branching cultivar with semi-determinate habit and Legat is a low branching cultivar with similar growth habit. Mielero, Yuno and Legat were arranged in a completely randomised design with 3 replicates. Plots consisted of  $15 \text{ m}^2$  (11 rows, 0.30 m apart and 4.5 m long) and seed rate was  $40 \text{ plant m}^{-2}$ . Plots were fertilised at sowing (200-200-100, N-P-K and  $54 \text{ kg S ha}^{-1}$ ) and a second N application ( $200 \text{ kg S ha}^{-1}$ ) was made when plants

reached anthesis in main stems. Plots were irrigated to supplement natural rainfall with the objective of avoiding water shortage. Data were subjected to analyses of variance and associations between variables were assessed by linear regression analysis.

#### MEASUREMENT AND CALCULATIONS

Plant samples were harvested 7 times during the crop cycle following development stages according to the scale proposed by Dracup and Kirby (1996) at:

- (i) stem elongation (2.1);
- (ii) inflorescence bud clearly visible (2.7);
- (iii) mainstem anthesis (3.3);
- (iv) first order anthesis (4.1),
- (v) one third of grain filling period (5.2)
- (vi) two third of grain filling period (5.4); and
- (vii) maturity harvest (5.7).

Biomass samples consisted of plants from 0.5 m long in the row except at maturity (5.7), when 1m of row was collected. Dry weight of leaves, stems and inflorescences were recorded. Grain yield and grain weight were measured at maturity and grain number was estimated by the ratio between grain yield and individual grain weight. Transmitted PAR was measured on clear days at noon (Hipps, 1983; Thorne *et al.* 1988) and measurements at ground level were taken as transmitted radiation (Slafer *et al.* 1990). The proportion of PAR radiation intercepted by the canopy was calculated as the ratio between: (i) the difference between incident and transmitted PAR; and (ii) incident PAR. The dynamic of PRI at the pre-anthesis period was estimated by an exponential equation and data were fitted by an optimisation model (Jandel, 1991). At post-anthesis, a quadratic polynomial equation was used and data were fitted by Microsoft Excel (2003).

Incident global radiation was measured every 15 minutes in a meteorological station located ca. 1 km from the experimental site. The amount of radiation intercepted by the crop was calculated as the product of PRI and incident global radiation. Accumulated intercepted radiation ( $\sum$ RI) was calculated from stem elongation (2.1), ca. 52 days after emergency (DAE), to physiological maturity. Radiation use efficiency (RUE) was calculated as the slope between accumulated biomass and  $\sum$ RI.

## RESULTS AND DISCUSSION

### GRAIN YIELD, BIOMASS AND HARVEST INDEX

Cultivars showed different ( $p < 0.001$ ) grain yield, biomass and HI (Table 1). Yuno, the high first order branching cultivar, reached the highest grain yield. This cultivar out-yielded Legat (low basal branching) and Mielero (high basal branching) by 45 and 65%, respectively. The higher grain yield of Yuno was the consequence of both biomass and HI values (Table 1). On the other hand, Legat showed the lowest biomass, while Mielero reached the lowest HI. For this reason,

there was not association between grain yield and either biomass or HI as it was previously found in *Lupinus albus* cultivars (Cowling *et al.* 1998; Julier *et al.* 1993). Differences in grain yield and biomass, mainly in the low branching cultivar (Legat) could be ascribed to its determined growth habit, which has been associated with low biomass production (Julier *et al.* 1993).

Grain yield components also showed differences between cultivars. Yuno had higher ( $p < 0.001$ ) grain number  $m^{-2}$  than Legat and Mielero, and similar grain weight than Legat. Mielero reached the lowest ( $p < 0.01$ ) grain weight (Table 1).

### RADIATION INTERCEPTION AND RADIATION USE-EFFICIENCY

The effect of cultivars on biomass at maturity was due to differences ( $p < 0.001$ ) in both physiological determinants.  $\sum$ RI reached by Mielero, Yuno and Legat were 962, 828 and 747  $MJ m^{-2}$ , respectively, while contrasting RUE values were showed by these cultivars: 1.80, 2.12 and 1.46  $g MJ^{-1}$ . Therefore, biomass of Yuno at maturity was mainly explained by higher RUE than Mielero and Legat. RUE showed by Yuno in the present experiment was higher than values reported previously for *L. angustifolius* (between 0.72 and 1.46  $g MJ^{-1}$  in Ayaz *et al.* 2004; Gregory and Eastham, 1996 and Thomson and Siddique, 1997) and *L. albus* (between 0.84 and 1.90  $g MJ^{-1}$  in Duthion *et al.* 1994 and Thomson and Siddique, 1997) but lower than the maximum RUE value reported in the literature for *L. albus*: 3.13  $g MJ^{-1}$  (Shiled *et al.* 2002).

To have a better picture of the causes involved in  $\sum$ RI and RUE differences between cultivars during the whole crop cycle, the performance of these biomass determinants, together with other associated traits, were evaluated at pre- and post-anthesis.

At anthesis (stage 3.3), similar ( $p > 0.05$ ) biomass was found between cultivars (Table 2). The same was true during early phases of the crop cycle (Fig. 1a, Fig. 2). Similar to biomass, RUE was not affected by cultivars. However,  $\sum$ RI showed differences between cultivars (Table 2). Legat reached higher  $\sum$ RI than Yuno and Mielero (Table 2). This was the consequence of higher radiation interception efficiency of Legat (Fig. 3), while time to anthesis was similar between cultivars (97, 92 and 96 days after emergence in Mielero, Yuno and Legat, respectively).

In the light of similar biomass values found at anthesis, cultivars differences on biomass at maturity were due to the post-anthesis period where Yuno and Mielero over-yielded Legat by 113 and 135%, respectively (Table 2). During this period,  $\sum$ RI and RUE were different between cultivars. Legat showed the lowest values of both biomass determinants. Difference in  $\sum$ RI were completely explained ( $R^2 = 1$ ,  $p < 0.001$ ) by the length of the post-anthesis period (Fig. 1b). On the other hand, Yuno reached the highest RUE and Legat the lowest (Table 2). In addition, the high first order branching cultivar Yuno not only

showed higher RUE at post-anthesis than the other cultivars but it also reached higher values than during the pre-anthesis period. This is in agreement with the study by Supasilapa *et al.* (1992) where higher RUE values were reported after the rapid pod filling period than at previous phases. Although only a cautious hypothesis can be offered for this work the strength of the sink seems to be the cause of the higher post-anthesis RUE showed by Yuno regarding the positive association found between RUE and grain number per unit of biomass at anthesis (Fig. 4). This ratio, used by Miralles and Slafer (1997) in wheat, indirectly reflects the source-sink balance during the post-anthesis period. Therefore, the highest RUE showed by the high first order branching cultivar could be interpreted as a regulatory effect of the sink size on RUE after anthesis.

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**Table 1.** Yield, biomass, harvest index (HI), grain number (GN) and grain weight (GW) of the three cultivars of *Lupinus luteus*.

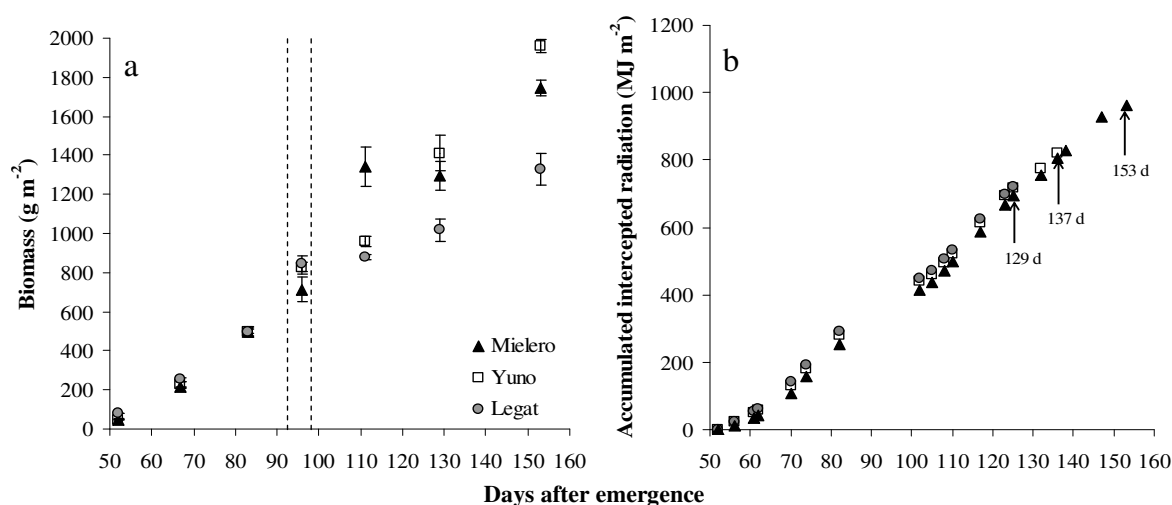
Cultivar	Yield (g m <sup>-2</sup> )	Biomasa (g m <sup>-2</sup> )	HI (%)	GN (m <sup>-2</sup> )	GW (mg)
Mielerero	389.5b	1745.9a	22.3b	3853a	101.3b
Yuno	643.2a	1959.3a	32.8a	5590b	115.2a
Legat	442.7b	1329.5b	33.3a	3483a	127.1a
s.e.	39.6	96.5	1.8	334	4.0

Letters show differences at  $p < 0.05$ .

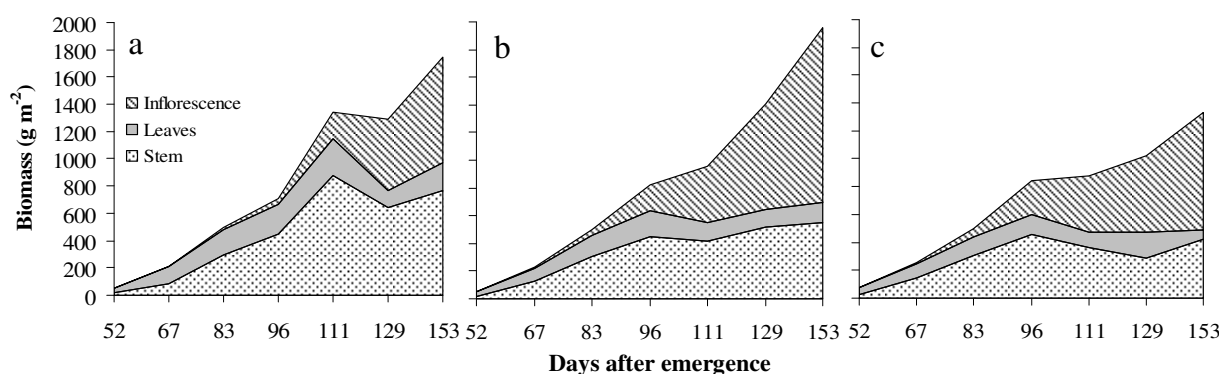
**Table 2.** Biomass, accumulated intercepted radiation ( $\Sigma$ RI) and radiation use-efficiency (RUE) of the three cultivars of *Lupinus luteus* at pre- and post-anthesis.

Period	Cultivar	Biomasa ( $g\ m^{-2}$ )	$\Sigma$ RI ( $MJ\ m^{-2}$ )	RUE ( $g\ MJ^{-1}$ )
Pre-anthesis	Mielerio	711.6a	365.7b	1.74a
	Yuno	822.2a	356.0b	1.79a
	Legat	845.0a	401.9a	1.89a
Post-anthesis	Mielerio	1033.6a	596.4a	1.46b
	Yuno	1137.1a	472.2b	2.43a
	Legat	484.5b	344.7c	1.02c

Letters show differences at  $p < 0.05$ .



**Fig. 1.** Relationship between biomass (a) and accumulated intercepted radiation (b) and time after emergence of cultivars Mielerio (▲), Yuno (□) and Legat (●). In a, Dotted line shows the date of anthesis. In b, arrows show physiological maturity of each cultivar.



**Fig. 2.** Biomass accumulation in different organs throughout the crop cycle of the three cultivars of *Lupinus luteus*: Mielerio (a), Yuno (b) and Legat (c).

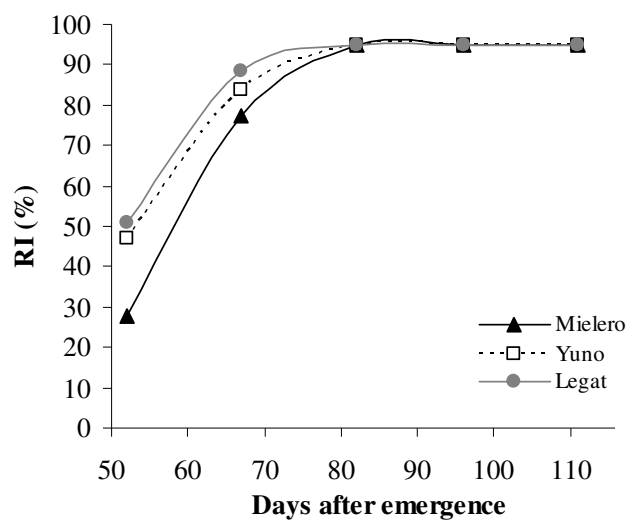


Fig. 3. Dynamic of radiation interception of the three cultivars of *Lupinus luteus*: Mielero (▲), Yuno (□) and Legat (●).

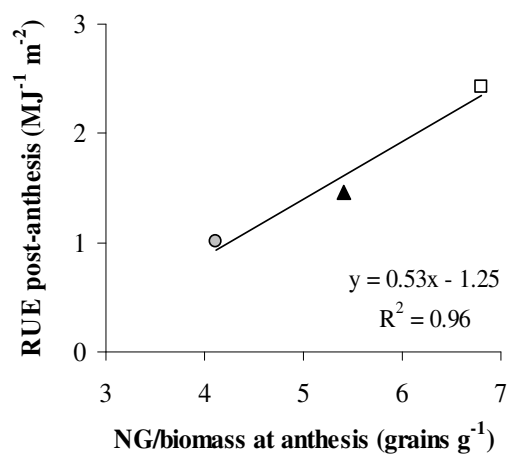


Fig. 4. Relationship between RUE at post-anthesis and the ratio between grain number and biomass at anthesis of the three cultivars of *Lupinus luteus*: Mielero (▲), Yuno (□) and Legat (●).