

# Dry Matter and Nitrogen Accumulation During Vegetative and Grain Filling of Lentil (*Lens culinaris* Medic.) as Affected by Nitrogen Rates

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## Abstract

This research aimed to determine the effect of different levels of nitrogen (N) on the growth, yield and the N accumulation of lentil plants grown under rain-fed conditions. The two-year field experiments with lentil were arranged in a randomised complete block design. Nitrogen was applied at four rates (0, 20, 40 and 60 kg ha<sup>-1</sup>) and all of the plots received half of the N rates before sowing in October and the remaining N rate in spring. The plants were harvested in the following stages: the first multifoliate leaf unfolding at the fifth node (V5) full seed or seed on nodes 10-13 that fill pod cavities (R6) and maturity (R8). The dry weight and N concentration of the shoot (leaf+stem), pod wall, and seed were then measured. It has been found that N application significantly affected the lentil characteristics. The maximum biomass accumulation and N accumulation were obtained at R6, and the N fertiliser had a positive effect on the seed weight and N accumulation. It can be suggest that 20 kg N ha<sup>-1</sup> will increase the per-plant dry matter and N accumulation of the seeds under rain-fed conditions.

**Keywords:** dry matter, growth stage, lentil, nitrogen accumulation, nitrogen fertiliser, seed filling stage

## Introduction

Legumes crops are important agricultural crops worldwide grown primarily for their high seed protein content (Malhi *et al.*, 2007; Niri *et al.*, 2010; Soltani *et al.*, 2006; Togay *et al.*, 2005; Walley *et al.*, 2007). One important benefit of legume crop production is the ability of these crops to form symbiotic associations with nitrogen (N)-fixing *Rhizobium* bacteria, thereby reducing their dependence on inorganic N fertilisers. It has long been recognised that N fertiliser represents the main economic and energy costs of continuous cropping systems. Generally, it is assumed that a well-inoculated legume crop can fix sufficient quantities of N to eliminate the need for N fertiliser input during the growth season of the legume crop (van Kessel and Hartley, 2000). However, legume crops have high grain protein contents in their grain; thus, the net export of N to grain is frequently high and often exceeds the total amount of fixed N in the biomass (Beck *et al.*, 1991).

Being a legume, lentil (*Lens culinaris* Medic.) can form symbiotic associations with *Rhizobium* bacteria and, under favourable conditions, biologic N fixation by lentil can reach as high as 20 kg N ha<sup>-1</sup>yr<sup>-1</sup> (McNeil and Materne, 2007). The application of a suitable amount of N fertiliser in lentil has been reported to increase the dry matter and N uptake (Malhi *et al.*, 2007; Niri *et al.*, 2010; Togay *et al.*, 2005). Indeed, increased rates of fertilizer application have steadily increase, the dry matter, seed yield, and N accumulation in crops. However, information on the accumulation and distribution of biomass and N accumulation

in lentil plants during the growing season under rain-fed conditions is lacking. Therefore, the objective of this study was to determine the effects of different levels of N on the plant growth, seed yield, and N accumulation of lentil grown under rain-fed conditions.

## Materials and methods

Two-year field experiments using lentil were established in 2006-2007 and 2007-2008 in the fields of the Faculty of Agriculture in Eskisehir, Turkey (39°48' N; 30°31' E). The soil of the experimental fields was slightly alkaline during the two years. The soil of the research area in the first year had a low water-holding capacity, was alkaline (pH 8.1) and calcareous (65% CaCO<sub>3</sub>), and contained a low amount of organic matter (1.2%). The P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O contents were sufficient in the first year; however, in the second year, the organic matter was at a medium level, the P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O contents were low, and the soil was loamy in texture. The long-term (1975-2007) total rainfall and average temperature of the location are 289.7 mm and 8.4°C, respectively (Tab. 1). The weather conditions during the two years were different. During the 2006-2007 growing season, there was quite a lot of rainfall during the period of seed filling. In contrast, the 2007-2008 season was hotter during the seed filling stage.

The experimental design was a randomised complete block design with four replications, and the experimental plots measured 5.4 m<sup>2</sup>. The lentil cultivar, 'Kayı-91', was used as the research material. The seeds were sown by hand

Tab. 1. Monthly precipitation and temperature values for September through June in 2006-2007 and 2007-2008 and an extended period (30 years) in Eskisehir

	Total rainfall (mm)			Mean temperature (°C)		
	Long period	2006/07	2007/08	Long period	2006/07	2007/08
September	93.0	0.0	15.4	16.7	16.6	17.7
October	47.5	19.1	16.4	11.7	12.6	12.6
November	16.8	91.7	32.9	5.6	3.9	4.9
December	6.8	46.1	34.7	1.4	-0.7	0.6
January	42.2	13.1	28.6	-0.4	0.0	-3.5
February	14.2	2.7	23.0	0.7	1.5	0.0
March	24.0	29.9	26.0	4.6	5.4	8.4
April	25.0	38.1	41.1	9.6	7.5	11.5
May	65.6	14.4	38.9	14.9	17.8	14.3
June	58.6	2.8	22.7	19.0	20.8	20.2
Total	257.9	393.7	289.7			
Mean				8.38	8.54	8.67

on October 9<sup>th</sup> in the first year and on October 2<sup>nd</sup> in the second year at a depth of 5 cm, with 6 rows and a row spacing of 30 cm. Phosphorus fertilisation was carried out at sowing (60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) in the form of triple superphosphate (0-45-0). Nitrogen fertilisation was applied as ammonium sulphate (21-0-0-24) at four rates (0, 20, 40 and 60 kg ha<sup>-1</sup>), and all of the plots received half of the N before sowing and the remaining N in the spring when plants were at the stage of the second bifoliate leaf unfolding at the fourth node (V4) (Erskine *et al.*, 1990).

Plants in the stage of the first multifoliate leaf unfolding at the fifth node (V5), full seed or seed on nodes 10-13 that filled the pod cavities (R6) and maturity (R8) were harvested. At R6 and R8, the dry weight and N concentration of the shoot (leaf+stem), pod wall, and seed were measured. The sampled material was dried at 65°C to achieve a constant weight. All of the N measurements were total N and were based on the Kjeldahl method. The N accumulation was calculated by multiplying the dry weight of the shoot, pod wall, and seed by the N concentration contained within them. The data were subjected to an analysis of variance (ANOVA), and the means were compared by the least significant difference (LSD) at confidence level using MSTAT-C computer programs.

## Results and discussion

The analysis of the variance of the data for the influence of N applications on the dry matter, N concentration, and N accumulation at different growth stages of lentil is shown in Tab. 2. The growth stage, N rate, and the interaction of the growth stage and N rate significantly affected the dry weight of the shoot dry matter (P<0.01), pod wall (P<0.01), and seed per plant (P<0.01). There was a decrease in the dry weight of the shoot and pod wall and an increase in the dry weight of the seed with the growth stage and seed yield per plant during the second year due to the weather conditions (Tab. 3). The observed difference may be explained, in part, by the slightly warmer temperatures (when averaged throughout the crop cycle) during the second year. However, it is more likely due to the higher rainfall (March to June -128.7mm) after top-dressing in the second year, especially during the stage of reproductive growth, which encouraged continued branch production after flowering. A high rainfall and high temperature throughout the grain-filling period can have a significant effect on the seed weight. Such a dramatic difference in the dry weight of the seeds per plant under disordered weather conditions has previously been observed

Tab. 2. Results of analysis of variance (mean squares) to analyse the dry matter, N concentration and N accumulation of lentil at different growth stages

Source	d.f. <sup>1</sup>	Dry matter of shoot	N conc. of shoot	N accum. of shoot	d.f. <sup>2</sup>	Dry matter of pod wall	N conc. of pod wall	N accum. of pod wall	Dry matter of seed	N conc. of seed	N accum. of seed
						2006/07					
N rate	3	1776288**	0.29**	1256**	3	273658**	0.322**	78.75**	360668**	0.58**	379.3**
Growth stage	2	50393003**	15.06**	6317**	1	2643850**	0.004ns	875.5**	2530687**	0.35*	2729**
N×G	6	693397**	0.064**	237**	3	123854**	0.165**	56.22**	180299**	0.45**	133.5**
						2007/08					
N rate	3	917990**	0.045ns	819**	3	42940**	0.480**	12.23*	122052**	0.131**	177.4**
Growth stage	2	49320273**	10.05**	15478**	1	5007821**	0.446**	11060**	11142740**	1.319**	13102**
N×G	6	752722**	0.123**	941**	3	294683**	0.037ns	309.9**	432359**	0.070**	860.4**

d.f.: degree of freedom; <sup>1</sup>sampling time is V5, R6 and R8; <sup>2</sup>sampling time is R6 and R8; \*significant at 5%; \*\*significant at 1%; ns-non-significant

in lentil (Whitehead *et al.*, 2000) and safflower (Dordas and Sioulas, 2009). The relationship between the amount of plant biomass amount and seed yield for flax has also been reported to be influenced by weather conditions or genotype-environment interactions (Casa *et al.*, 1999; Diepenbrock *et al.*, 1995).

The shoot and pod wall weight were the highest at the filled pod cavities (R6). The total above ground biomass increased after anthesis in both years. There was a decrease in the total dry matter between R6 and R8, which has previously been reported in wheat (Papakosta and Gagianas, 1991) and safflower (Dordas and Sioulas, 2009). Nitrogen shortage and N excess can affect assimilate partitioning between the vegetative and reproductive organs, and dry matter partitioning (depending on the sink number, sink activity and seed number) is strongly associated with assimilate availability at flowering (Dordas and Sioulas, 2009). Thus, the high dry matter accumulation before maturity has an effect on the yield volume.

The dry matter accumulation of the shoot varied according to the N levels and growing stage (Tab. 3). The dry weight of the shoot during the V5 and R6 stages increased under 40 kg N ha<sup>-1</sup> in the first year and 20 kg N ha<sup>-1</sup> in the second year and decreased under 60 kg N ha<sup>-1</sup> in both years. Nevertheless, the dry matter of the shoot at R8 was not changed with the increasing N rate even when there was no difference between the control and N treatment plots in the dry matter of the shoot for the first year. The effect of the shoot on the total dry weight of the plant at R6 and R8 was 84 and 72% under 60 kg N ha<sup>-1</sup>, respectively, in the first year and 71% under 20 kg N ha<sup>-1</sup> and 51% under 60 kg N ha<sup>-1</sup> in the second year. The dry weight of the pod wall was the highest in the control plot at R6 and R8 in the first year and at R6 under 40 kg N ha<sup>-1</sup> and at R8 under 20 kg N ha<sup>-1</sup> in the second year. Interestingly, the contribution of the pod wall to the total dry weight per plant at R6 and R8 for both years occurred in the control plot at R6 (20-22%) and in the 20 kg N ha<sup>-1</sup> plot at R8. The seed weight per plant was the highest at R6 and R8 in the control in the first year (Tab. 3). However, the seed weight per plant, as was also the case with the pod wall, was the highest under 40 kg N ha<sup>-1</sup> (after the control) at R6 and 20 kg N ha<sup>-1</sup> at R8. The dry weight of the whole plant was the highest under 40 kg ha<sup>-1</sup> in the first year and 60 kg ha<sup>-1</sup> in the second year.

The results of N application showed that although the dry matter of the shoot was the highest in the V5 and R6 stages at an application of 40 kg N ha<sup>-1</sup>, there was no difference in shoot weight between control and 40 kg N ha<sup>-1</sup> at harvest time under the higher rainfall conditions in the first year. It was found that N application did not increase in dry weight of the seed per plant at harvest time in the first year; however, the ration in the total plant weight of the seed yield per plant was affected by 20 kg N ha<sup>-1</sup> rate (36 and 41%) in both years. Previous studies have stated that the grain yield was increased by increasing the rate

of N application in lentil (Niri *et al.*, 2010; Togay *et al.*, 2005).

The growth stage, N rate and interaction of the growth stage and the N rate significantly affected the N concentration of the shoot, pod wall, and seed per plant ( $P < 0.01$ ), and only the effect of the N rate and the interaction of the N concentration on the shoot and pod wall were not significant ( $P > 0.05$ ) (Tab. 2). The highest N concentration in the shoot occurred at V5, whereas the highest N concentration in the pod wall and seed was at R6 (Tab. 4). The N concentration of the shoot at V5 was higher in the plots with applied N than in the control plot during the two-year period. The N concentration of the shoot during the vegetative period (V5) was 31.93-39.91 mg g<sup>-1</sup>, which is consistent with the values reported for other legumes. For instance, Turpin *et al.* (2002) found an initial value of 30 mg g<sup>-1</sup> for the stem N concentration in faba bean.

The N concentration of the pod wall did not increase compared with the control at R6 for both years or at R8 in the second year (Tab. 4). Whereas the N concentration of the seed was the highest under 20 kg N ha<sup>-1</sup> at R6 in the first year and 60 kg N ha<sup>-1</sup> at R8 in the second year, the highest N concentration in the seed was found under 60 kg N ha<sup>-1</sup> at R6 and R8 for both years. The N concentration of the seed declined during the seed-filling period from R6 to R8. This decrease in the N concentration of the seed is consistent with the values reported for chickpea by Saxena (1984) and Soltani *et al.* (2006), who stated that the total N concentration of grain continues to increase as the grain grows but that the N decreases because starch accumulates faster than N. A similar decline in the N concentration of grain has been found by Lhuillier-Soundele *et al.* (1999) in pea and soybean (Hayati *et al.*, 1995), whereas a relatively constant grain N concentration has been reported for soybean, cowpea, and mungbean (Muchow *et al.*, 1993).

The 60 kg N ha<sup>-1</sup> rate resulted in the highest N concentration in the stem, pod wall, and seed during the two years. The effect of the N fertiliser on the N concentration of the shoot, pod wall, and seed was significantly positive. Nitrogen is involved in vital plant functions, such as photosynthesis and protein formation (Marschner, 1995). Growth parameters, including the leaf area index, leaf photosynthesis, and the N concentration of plant tissue, may decrease due to unsatisfactory N availability (Caliskan *et al.*, 2008). The results obtained in this study indicated that the N fertilisation had a positive effect on the N concentration of the seed, a finding in agreement with Niri *et al.* (2010).

Nitrogen fertiliser, the growth stage, and the interaction of the N fertiliser and growth stage were significant in the N accumulation of the shoot, pod wall, and seed (Tab. 2); however, the accumulation of N in different plant parts varied between the years (Tab. 5). The accumulation was higher in the second year for all of the N-application plots due to the weather conditions: the dry matter accumulation and N concentration were low, affecting the accu-

Tab. 3. Dry matter (mg/plant) of lentil plants at different growth stages during 2006-2007 and 2007-2008

N rate (kg ha <sup>-1</sup> )	Vegetative <sup>1</sup>		Filled pod cavities <sup>2</sup>					Maturity <sup>3</sup>					Total		
	Shoot	Shoot	Ration in total plant (%)	Pod wall	Ration in total (%)	Seeds per plant	Ration in total (%)	Total	Shoot	Ration in total plant (%)	Pod wall	Ration in total plant (%)		Seeds per plant	Ration in total plant (%)
2006-2007															
Control	1537b	4282d	69	1237a	20	667a	11	6186c	2524a	55	536a	12	1490a	33	4550a
20	1578b	4478c	77	799c	14	561b	10	5838d	1908b	50	512b	13	1380b	36	3800b
40	2135a	5756a	77	1120b	15	646a	9	7522a	2553a	68	272c	7	911c	24	3736b
60	1464c	5659b	84	668d	10	426c	6	6753b	2550a	72	204d	6	769d	22	3523c
LSD <sub>0.01</sub> (N) Shoot 34.69; Pod wall 15.55; Seed per plant 20.70															
LSD <sub>0.01</sub> (G) Shoot 30.04; Pod wall 11.00; Seed per plant 14.63															
LSD <sub>0.01</sub> (N×G) Shoot 60.09; Pod wall 22.00; Seed per plant 29.27															
2007-2008															
Control	1974c	4713d	63	1623	22	1093d	15	7429	3242a	49	879	13	2443b	37	6564
20	2571a	6252a	71	1343	15	1178c	13	8773	3107b	44	1074	15	2897a	41	7078
40	2391b	5371c	62	1771	20	1532a	18	8674	2859d	50	645	11	2160d	38	5664
60	1851d	5961b	68	1595	18	1273b	14	8829	3008c	51	569	10	2297c	39	5874
LSD <sub>0.01</sub> (N) Shoot 12.28; Pod wall 18.82; Seed per plant 0.12															
LSD <sub>0.01</sub> (G) Shoot 10.64; Pod wall 13.31; Seed per plant 0.09															
LSD <sub>0.01</sub> (N×G) Shoot 21.28; Pod wall 26.62; Seed per plant 0.18															

There is no difference in the same letter, <sup>1</sup>stage of V5; <sup>2</sup>stage of R6; <sup>3</sup>stage of R8

Tab. 4. Nitrogen concentration ( $\text{mg g}^{-1}$ ) of shoot, pod wall and seed of lentil

N rate ( $\text{kg ha}^{-1}$ )	Vegetative <sup>1</sup>		Filled pod cavities <sup>2</sup>		Maturity <sup>3</sup>		
	Shoot	Shoot	Pod wall	Seed	Shoot	Pod wall	Seed
2006-2007							
Control	31.93c	15.80	16.50b	38.97a	14.95c	19.91ab	30.53b
20	32.35ab	15.46	16.35b	41.37a	14.72c	14.78c	38.25a
40	33.95ab	15.92	20.27a	33.74b	17.86b	17.50bc	35.93a
60	34.92a	16.51	19.48ab	38.57a	20.86a	21.25a	39.50a
LSD <sub>0.01</sub> (N) Shoot 1.51; Pod wall 2.40; Seed per plant 3.29							
LSD <sub>0.01</sub> (G) Shoot 1.30; Pod wall 1.70; Seed per plant 2.33							
LSD <sub>0.01</sub> (N×G) Shoot 2.61; Pod wall 3.40; Seed per plant 4.66							
2007-2008							
Control	35.00b	23.20	33.80	42.09b	26.24a	24.82	37.72b
20	38.76a	24.54	38.78	41.47c	22.55b	28.49	38.69b
40	39.91a	23.51	36.24	43.80ab	25.38ab	24.10	37.22b
60	37.85a	23.77	39.05	43.93a	24.14ab	29.36	41.42a
LSD <sub>0.01</sub> (N) Shoot 1.51; Pod wall 2.16; Seed per plant 1.28							
LSD <sub>0.01</sub> (G) Shoot 1.42; Pod wall 1.53; Seed per plant 0.91							
LSD <sub>0.01</sub> (N×G) Shoot 2.84; Pod wall 3.05; Seed per plant 1.81							

<sup>1</sup>stage of V5; <sup>2</sup>stage of R6; <sup>3</sup>stage of R8

mulation of N and, therefore, driving the great difference found between the years. The highest total N accumulation was found at R6 and decreased throughout maturity in both of the years. The highest total N accumulation occurred at R6 under  $60 \text{ kg N ha}^{-1}$  in the second year, indicating that 54% of the N accumulation occurred in the shoot and the remaining N was allocated to the pod wall (24%) and seed (22%). However, the highest total N accumulation at maturity was 33% in the shoot, and the remaining N was allocated to the pod wall (14%) and seed (53%). As has been previously reported, N accumulation seems to depend upon the needs of the plant rather than being determined by the N concentration in the rooting medium. Indeed, rates of N acquisition seem to be controlled by specific demand-driven regulatory mechanisms (Schiltz *et al.*, 2005).

Pengelly *et al.* (1999) and Soltani *et al.* (2006) reported that the highest proportion of N accumulation was partitioned to the stem and the leaves at the seed-filling stage. A decrease in the N level over the crop growth period has been reported in both crops and isolated plants (Gastal and Lemaire, 2002; Jeuffroy *et al.*, 2002; Soltani *et al.*, 2006). Two reasons have been given for the phenomenon. Firstly, the ratio of leaf (metabolic tissue with high N levels) to stem (structural tissue with low N levels) decreases during growth. Secondly, the N from the shaded (self and mutual) parts of the canopy is recycled, providing some of the N required for growth, thus decreasing the N uptake over time. Malhi *et al.* (2007) also found that there was a large decrease in the uptake of nutrients in lentil and pea plants between the grain-filling to harvest stages. These authors attributed a decreased nutrient uptake in the seed to a decreased translocation of nutrients from the vegetative to reproductive parts during the reproductive stages

of the crops, although the decreased maximum nutrient uptake and decreased amount of nutrients at harvest may have also played a role in decreasing the nutrient uptake in the seeds at harvest.

Nitrogen accumulation at all growth stages was affected by the N fertiliser during the two years of the study. The nitrogen accumulation of the shoot in all of the growth stages was highest under an application of  $40 \text{ kg N ha}^{-1}$  in the first year and under  $20 \text{ kg N ha}^{-1}$  in the second year. Whereas the N accumulation decreased in the shoot and pod wall at harvest, it increased in the seed. The seed N accumulation at maturity was the highest under  $20 \text{ kg N ha}^{-1}$  during the two years, and the N accumulation in the seed did not increase with the increasing N rate. Similar effects of N fertiliser on nodulation and N fixation have been reported in studies of other legumes (Clayton *et al.*, 2004; Walley *et al.*, 2005). These results lead to the conclusion that when the conditions are favourable for nodulation and N fixation, the application of N fertiliser will partly replace the N from fixation without positively increasing the productivity of the plant. Moreover, the present findings for lentil are substantiated by those of El Mejahed (1993), who found that chickpea absorbed  $18 \text{ kg N ha}^{-1}$  from the soil during a normal year, and Niri *et al.* (2010), who reported the highest nitrogen uptake occurred under  $25 \text{ kg N ha}^{-1}$ .

The relationship that exists between N and the plant development, dry matter, and N accumulation in lentil plants grown under rain-fed conditions showed that the dry matter accumulation of the shoot varied according to the growth stages and that a maximum biomass amount accumulated at R6. The maximum biomass accumulation and N accumulation at harvest were lower in the first year in comparison to the second year, a finding that may be

Tab. 5. Nitrogen accumulation (mg N/g dry matter) of shoot, pod wall and seed

N rate (kg ha <sup>-1</sup> )	Vegetative <sup>1</sup>		Filled pod cavities <sup>2</sup>					Maturity <sup>3</sup>					Total		
	Shoot	Shoot	Ration in total (%)	Pod wall	Ration in total (%)	Seeds per plant	Ration in total (%)	Total	Shoot	Ration in total (%)	Pod wall	Ration in total (%)		Seeds per plant	Ration in total (%)
2006-2007															
Control	49.09b	67.65b	59	20.42b	18	25.98a	23	114.05	37.74c	40	10.68a	11	45.49b	48	93.91
20	51.06b	69.24b	66	13.07c	12	23.21a	22	105.52	28.08d	32	7.56b	9	52.72a	60	88.36
40	72.50a	91.63a	67	22.71a	17	21.79ab	16	136.13	45.60b	55	4.76c	6	32.74c	39	83.10
60	51.12b	93.42a	76	13.00c	11	16.45c	13	122.87	53.18a	60	4.34c	5	30.39c	35	87.91
LSD <sub>0.01</sub> (N) Shoot 4.39; Pod wall 1.52; Seed per plant 4.47															
LSD <sub>0.01</sub> (G) Shoot 3.80; Pod wall 1.08; Seed per plant 3.16															
LSD <sub>0.01</sub> (N×G) Shoot 7.60; Pod wall 2.16; Seed per plant 6.33															
2007-2008															
Control	69.10b	109.34d	52	54.86b	26	46.01c	22	210.21	85.07a	43	21.83b	11	92.15b	46	199.05
20	99.64a	153.42a	60	52.06b	20	48.83c	19	254.31	70.06b	33	30.61a	14	112.08a	53	212.75
40	95.41a	126.28c	49	64.19a	25	67.10a	26	257.57	72.56b	43	15.54c	9	80.40c	48	168.50
60	70.05b	141.70b	54	62.27a	24	55.93b	22	259.90	72.63b	39	16.70c	9	95.14b	52	184.47
LSD <sub>0.01</sub> (N) Shoot 5.72; Pod wall 2.76; Seed per plant 2.94															
LSD <sub>0.01</sub> (G) Shoot 4.95; Pod wall 1.95; Seed per plant 2.08															
LSD <sub>0.01</sub> (N×G) Shoot 9.91; Pod wall 3.91; Seed per plant 4.16															

<sup>1</sup>stage of V5; <sup>2</sup>stage of R6; <sup>3</sup>stage of R8

explained by the variation in the weather conditions between the years. Overall, the findings suggest that a sufficient supply of nutrients for high levels of biomass accumulation and N accumulation at early growth stages and the translocation of the biomass and N to the seed at later growth stages are of great importance for high yields in lentil. Nitrogen fertiliser had a positive effect on the seed weight and N accumulation in lentil. In conclusion, it is suggested that 20 kg N ha<sup>-1</sup> will increase the per-plant dry matter and N accumulation of the seeds under rain-fed conditions.

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