**Polish Journal of Agronomy**
**2010, 2, 44–49**

# The estimation of water demands of a determinate and traditional cultivars of faba bean (*Vicia faba* L.)

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**Abstract.** The experiment was conducted in a greenhouse of the Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy, in the Mitscherlich pots containing a mixture of 5 kg of garden soil and 2 kg of sand. The first-order factors were the two faba bean genotypes: 'Nadwiślański' – the traditional type (indeterminate) and 'Tim' – a determinate type, and the second-order factor was the substrate moisture content: 30, 50 and 70% field capacity (FWC), maintained throughout the growing season.

The potted plants were irrigated using the drip irrigation precision instrument coupled with an automatic controller. During the irrigation, the quantity of given water in the pot was recorded. The shortage of water in the soil adversely affected the dynamics of (mass) accumulation by the vegetative and generative organs of both faba bean cultivars, but the stronger negative impact of drought on the yield was observed on a determinate type than on the traditional type of faba bean 'Tim'.

In the initial stage of growth and development of faba bean both forms exhibited similar water requirements. The differentiation between the water requirements of faba bean cultivars became apparent only during the generative development of field bean and lasted from the flowering to the ripening stage. The determinate faba bean cultivar needed less water during the flowering–maturing period than traditional 'Nadwiślański' but water deficit during this period resulted in greater reduction of seed yield of 'Tim' than of 'Nadwiślański'.

**key words:** faba beans, a determinate cultivar, a traditional cultivar, water needs, soil moisture levels, % FWC, drought stress, growth and development, yielding

## INTRODUCTION

Adverse course of the weather conditions, mainly the lack of rainfall during the periods of flowering and pod setting, which are considered as critical to the growth and development of faba bean is one of the most important factors limiting the yield (Demidowicz, 1990; Jasińska, Kotecki, 1993; Michalska, 1993).

The drought occurring during this period causes falling of flower buds and flowers before fertilization, and later also the pods (Jasińska, Kotecki, 1995). As a result of those phenomena, the broad bean is a species the yields of which vary greatly from year to year (COBORU, 2008).

As faba bean yield is not a reliable and it has a relatively long period of vegetation there is not too much interest by farmers in cultivating faba bean although it is a very valuable protein plant. In this situation, the search for genotypes more resistant to drought stress becomes advisable. This issue is important because climate change during the recent years could result in increasingly long drought in spring and summer months in our country (Łabędzki, Leśny, 2008).

Thanks to considerable breeding progress determinate cultivars of bean were developed with modified morphology and differing in growth and development rate from traditional varieties (Martyniak, 1997). Previous studies showed that the determinate growth cultivars of bean give lower yield (Borowiecki et al., 1992; Kotecki, 1994) and are more sensitive to water shortage in the soil than the traditional cultivars (Podleśny, Kocoń, 2006). At the same time they produce a lower yield of biomass which indicates lower water requirements.

The aim of this study was to determine the water needs of morphological differentiated cultivars of faba bean necessary to obtain optimum seed yield and the estimation of the impact of water deficiency in soil on yield variability.

## MATERIALS AND METHODS

The experiments were conducted in 2004–2006, in the greenhouse of the Institute of Soil Science and Plant Cultivation, National Research Institute in Puławy, in Mitscher-

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*Received 23 March 2010*

lich's pots containing a mixture of 5 kg of garden soil and 2 kg of sand. Faba bean cultivars were the first factor of the experiment: 'Nadwiślański' – the traditional type (an indeterminate cultivar) and 'Tim' – a determinate type, and the second factor was a substrate moisture content: 30, 50 and 70% field water capacity (FWC) maintained throughout the growing season.

The experiments were conducted in a completely randomized layout. 10 seeds were sown in each pot and after emergence, some seedlings were thinned, leaving five plants in a pot. The following fertilization (g pot$^{-1}$) was applied: 0.1 – N, 1,1 – P and 1,4 – K in liquid form injected into the irrigation system, on two dates – at the emergence and at the 1$^{st}$–2$^{nd}$ leaf stage. The plants were watered using the precision instrument for the irrigation of the soil coupled with an automatic controller.

The amount of water given to the pot was recorded. The results were calculated per 40 plants m$^{-2}$ because it is at that density that faba beans are cultivated most frequently. Detailed observations of plant growth and development were carried out during the growing season. Dynamics of the emergence was defined as the percentage of the number of germinated plants with respect to the seeds sown.

To this end, during the emergence the plants were counted at intervals of 24 hours. The measurements of plant height in the major phases of their growth and development were also performed. The plants were harvested on two dates: at the flowering stage and at full maturity. The plant height was measured and the dry matter yield of individual plant organs was determined during harvest made at the flowering stage.

During the harvest performed at the stage of full maturity plant height as well as yield and its components were determined (the number of pods, number of seeds, seed weight and moisture content). The soil was washed from the pots on a fine-mesh metal sieves in order to determine root weight. The results representing the average of the three pots were analyzed statistically using the Tukey's confidence half-interval at the significance level of $\alpha = 0.05$.

## RESULTS AND DISCUSSION

The rate of germination and emergence of faba bean depended on the soil moisture. The earliest emergence and the best developed plants were on the soil with a moisture content of 50 and 70% field water capacity. On the soil with 30% field water capacity plant emergence was postponed about 3 days compared to the plants growing in the soil with higher moisture.

Number of germinating seeds and emerging plants significantly depended on the soil moisture. The poorest germination and later emergence of faba bean were observed on the soil with the lowest degree of humidity (30% FWC), and the best on the soil with 50% of FWC. Both, the decrease and the excessive increase in soil moisture content had a negative impact on the germination of seeds (Fig. 1).

The shortage of water in the soil adversely affected the growth of bean plants of both cultivars (Fig. 2) and reduced dry matter yield of the shoots (Fig. 3). The weight of stems and leaves of 'Nadwiślański' cultivar grown in the soil with a moisture content of 50 and 70% FWC was greater than the weight of faba bean growing in soil with a moisture content 30% of FWC respectively by: 34 and 47.5%; for 'Tim' cultivar these values were respectively: 53.8 and 55.4% .

The opposite was true of root weight. The underground mass of faba bean increased significantly along with decreasing soil moisture. This is explained by plant need to develop a longer root system which will be able to reach deeper into soil under water deficit conditions (Starck, 2002). Faba bean cultivar 'Nadwiślański' at all three levels of soil moisture produced a larger root system than did 'Tim' cultivar.

The mass of vegetative and generative organs of faba bean at the ripeness stage depended significantly on soil moisture. The smallest mass of leaves, stems, hulls, seeds and roots was produced by two cultivars of faba bean grown in the driest soil (Fig. 4). It is worth noting that, apart from the mass decrease of the aerial part, the weight of the root sys-

Table 1. Length of interstages periods of faba bean.

| Development stages | Nadwiślański | | | Tim | | |
|---|---|---|---|---|---|---|
| | soil moisture [% FWC] | | | | | |
| | 30 | 50 | 70 | 30 | 50 | 70 |
| Germination − seedling | 9 | 6 | 6 | 9 | 6 | 6 |
| Seedling – 2–3 leaf stage | 18 | 18 | 18 | 18 | 18 | 18 |
| 2–3 leaf stage – 5–6 leaf stage | 24 | 24 | 24 | 24 | 24 | 24 |
| 5–6 leaf stage – flowering | 12 | 14 | 16 | 12 | 14 | 16 |
| Flowering – pod setting | 11 | 14 | 15 | 9 | 11 | 12 |
| Pod setting – seed filling | 12 | 15 | 16 | 8 | 10 | 12 |
| Seed filling – full maturity | 21 | 24 | 27 | 18 | 23 | 24 |
| Total | 107 | 115 | 122 | 98 | 106 | 112 |

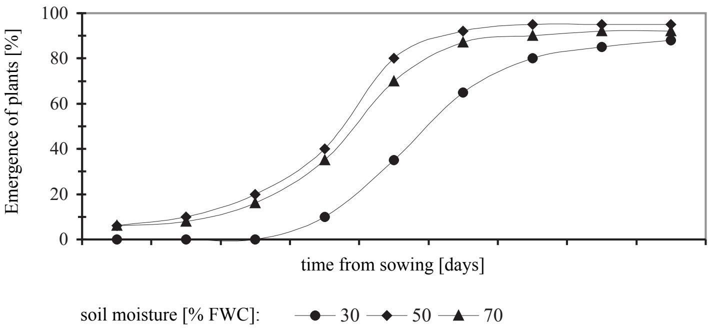


Fig. 1. Emergence of faba bean plants in terms of soil moisture.

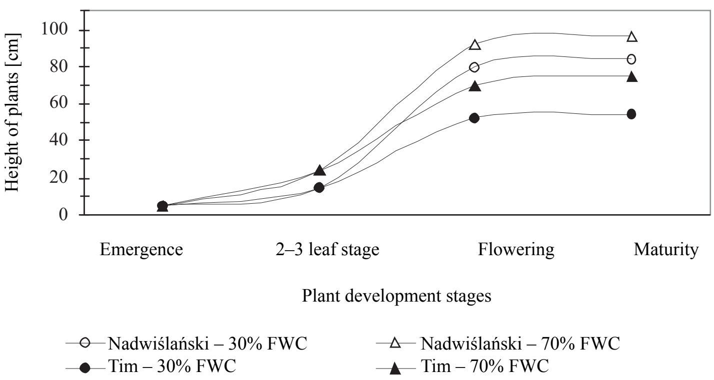


Fig. 2. Height of faba bean plant in dependence of soil moisture.

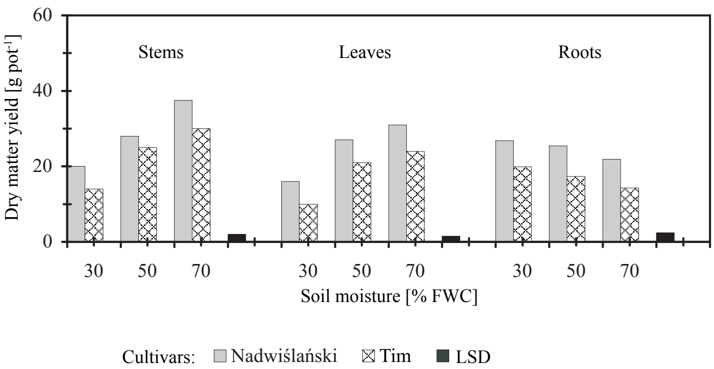


Fig. 3. Yield of dry matter yield of faba bean organs in flowering period.

tem declined as a result of insufficient soil moisture. This should be explained by the earlier maturing of the plants growing under conditions of water deficit and the related early necrosis and decomposition of root system.

The impact of soil moisture on plant growth and development was observed. The duration of some phenological phases of faba bean was shortened along with a reduction of soil moisture. Plants cultivated on soil with lowest degree of moisture (30% FWC) began flowering after 63 days, pod setting after 73 days and reached maturity after 103 days from germination, while for plants grown on soil with moisture 70% FWC these values were: 64, 78 and 117 days respectively (means for both cultivars; Table 1). Earlier flowering of the plants growing under stress caused mutual competition for water, light and nutrients was also observed by Kotecki (1990) and Podleśny (1994) for other crop species.

Water shortage-dependent yield reduction observed at full maturity was, just as that occurring at the flowering stage, more pronounced in cv. ‘Tim’ than in cv. ‘Nadwiślański’.

Higher yields of seeds and pod husks were provided by plants of both cultivars grown under conditions of greater soil moisture.

However, the differences in the yield of generative organs due to reduction of the soil water content were significantly lower in the case of a traditional bean cultivar ‘Nadwiślański’ than a determinate faba bean cultivar ‘Tim’. The reduction of seed yield as a result of a water content decrease from 70 to 50 and 30% FWC of ‘Nadwiślański’ cultivar was 16.3 and 38.8% respectively, and of ‘Tim’ cultivar 20.0 and 53.4%.

The lower ratio of root mass to the aboveground parts also confirms reduced resistance to drought of ‘Tim’ compared to ‘Nadwiślański’ variety (Podleśny, 2001). According to Grzesiak et al. (1997) it is one of the most important indicators largely determining the resistance of plants to drought stress, taken into account in the breeding of cultivars with increased tolerance to drought (Hurd, 1974; Tardieu, Katerji, 1991).

The greater sensitivity of traditional cultivars than that of determinate ones to the shortage of water in the soil is not a rule that applies to all leguminous species. The research of Bieniaszewski et al. (2003) showed that some determinate cultivars of yellow lupine are more resistant to drought than traditional ones.

The reduced yield was a consequence of a significant reduction in the number of pods per plant and number of seeds from one plant (Table 2) while the number of seeds per pod, considered as a varietal characteristic did not change significantly (Xia, 1997). The research of Sammler et al. (1982) and Grzesiak et al. (1989) showed that during drought the bean plants may shed flowers, or even set pods, which, in consequence, results in reduced seed yield.

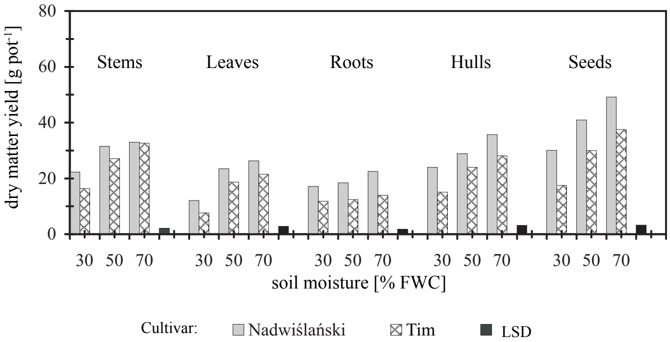


Fig. 4. Yield of dry matter of faba bean plants at maturation period.

Table 2. Components of seed yield of faba bean.

| Cultivar | Soils moisture [% FWC] | Number of pods per plant | Number of seeds per pod | Number of seeds per plant | Weight of 1000 seeds [g] |
|---|---|---|---|---|---|
| Nadwi-ślański | 30 | 4.6 a | 3.1 a | 14.4 a | 446 a |
| | 50 | 5.7 b | 3.3 a | 18.6 b | 458 a |
| | 70 | 6.4 b | 3.1 a | 19.8 c | 459 a |
| Tim | 30 | 4.0 a | 2.4 a | 9.6 a | 434 a |
| | 50 | 6.5 b | 2.2 a | 14.5 b | 440 a |
| | 70 | 6.1 b | 2.5 a | 15.3 b | 440 a |

Numbers in columns marked with the same letters do not differ significantly

The authors of other studies suggested that drought may reduce the density of pods per faba bean plant by almost 65% (Mwanamwenge et al., 1999) and decrease seed yield by up to 70% (Lopez et al., 1996). Podleśny (2003) and Bieniaszewski et al. (2003) showed in their previous studies the similar relationships with regard to the yellow and white lupine.

The 'Nadwiślański' cultivar of faba bean needed about 29% more water to produce the optimum yield of vegetative and generative organs than did the cultivar 'Tim' (Table 3). Meanwhile, the research results presented in this study also showed that the 'Nadwiślański' cultivar of faba bean is less sensitive to water deficit in the soil.

It' can therefore be assumed that the 'Tim' cultivar of bean, because of its smaller biomass of organs, consumes less water during the growing season but its weaker root system caused that it requires a more uniform water supply. The long-term water shortage in the soil reduces its yield more severely comparing to the traditional cultivar 'Nadwiślański'.

It is worth noting that the calculated amount of water for the whole period of vegetation is very similar to that obtained in Dzieżyc's studies (1989). It is very interesting because the study of Dzieżyc (1989) was conducted under field conditions, whereas the presented results came from pot experiments.

Table 3. Water requirements of faba bean during the vegetation period.

| Month | Nadwiślański | | Tim | | According to Dzieżyc (1998) |
|---|---|---|---|---|---|
| | $dm^3$ per plant | mm $m^{-2}$ | $dm^3$ per plant | mm $m^{-2}$ | |
| April | 0.87 a | 34.6 a | 0.87 a | 34.6 a | 39.4 |
| May | 1.67 b | 66.8 b | 1.67 b | 66.8 b | 69.9 |
| June | 2.24 c | 89.6 c | 1.81 b | 72.6 b | 85.7 |
| July | 2.44 c | 97.5 c | 1.86 b | 74.3 b | 90.8 |
| August | 1.60 b | 63.9 b | 0.61 a | 24.3 a | 61.0 |
| Total | 8.82 | 352.4 | 6.82 | 272.6 | 346.8 |

Numbers in columns marked with the same letters do not differ significantly

Table 4. Water consumption by faba bean plants at different development stages ($dm^3 \cdot pot^{-1}$).

| Development stage | Nadwiślański | | | Tim | | |
|---|---|---|---|---|---|---|
| | soil moisture (% FWC) | | | | | |
| | 30 | 50 | 70 | 30 | 50 | 70 |
| Germination − seedling | 0.64 a | 1.04 a | 2.23 b | 0.64 a | 1.04 a | 2.23 a |
| Seedling – 2–3 leaf stage | 0.82 b | 1.54 a | 2.87 b | 0.82 a | 1.54 a | 2.87 a |
| 2–3 leaf stage – 5–6 leaf stage | 0.65 a | 1.11 a | 1.87 a | 0.65 a | 1.11 a | 1.87 a |
| 5–6 leaf stage – flowering | 0.91 a | 1.25 a | 2.73 b | 0.91 a | 1.25 a | 2.73 a |
| Flowering – pod setting | 3.40 c | 4.54 c | 7.43 c | 1.54 b | 3.24 b | 5.44 c |
| Pod setting – seed filling | 1.49 b | 2.84 b | 6.11 c | 1.34 b | 4.64 c | 9.13 d |
| Seed filling – full maturity | 3.54 d | 4.66 c | 9.53 d | 2.42 c | 2.91 b | 4.00 b |
| Total | 14.03 | 23.14 | 44.12 | 10.46 | 17.45 | 33.96 |

Numbers in columns marked with the same letters do not differ significantly

The research results obtained by Dzieżyc (1989) probably are related to the traditional bean cultivars which were widely used in agricultural research at that time. Many cultivars of bean with determinate growth are nowadays, on the "National list of cultivars" which increases their importance and justifies that line of research.

There is a lack of studies on determining the water needs of differentiated forms of faba bean at different stages of plant growth and development in literature. Most authors (Demidowicz, 1990; Grzesiak et al., 1989; Sammler et al., 1982) indicate high water needs of plants during flowering and pod setting, but these observations relate to traditional forms of faba bean or faba bean as a species without taking into account its morphologically diverse genotypes.

The data in Table 4 shows that both faba bean cultivars had a similar water demand in the initial period of growth and development. The differentiation between the water requirements of faba bean genotypes studied were revealed practically during the generative development of faba bean and lasted from flowering to ripening stage.

Generally it can be concluded that the determinate cultivar needed less water during flowering stage (considered as a critical) than the traditional cultivar 'Nadwiślański'. On the other hand the deficit of water in that period resulted in a greater reduction of yield of the determinate cultivar 'Tim' than in cv. 'Nadwiślański'.

The strong convergence of obtained results concerning their water needs with the data achieved by Dzieżyc (1989) from the faba bean cultivated in the field conditions shown in the present study suggests that similar water needs depending on the different forms in the particular stages of growth and development of faba bean are present also in the field conditions.

## CONCLUSIONS

1. The faba bean plants growing in soil with lowest water content were shorter and some of their phenological stages were altered: they began the flowering, pod setting, and maturity earlier than the plants growing in the highest soil moisture conditions.

2. The reducing of the water content in the soil strongly inhibits the development and yielding of faba bean cultivars. 'Tim' – a form of the determinate growth type gave the lowest yield when grown in the soil with the lowest moisture conditions. The best yield was gained from the indeterminate cultivar 'Nadwiślański' in optimum moisture content of 70% FWC.

3. The reduction of the seed yield obtained from plants growing under conditions of low soil moisture resulted from the significantly lower density of pods per plant and the smaller amount of seeds from a single plant.

4. Both faba bean forms exhibited similar water requirements in the initial period of growth and development. The differentiation between faba bean genotypes studied concerning the water requirements was revealed only during the generative development of faba bean and lasted from the flowering to ripening stage. 'Tim' cultivar needed less water than the 'Nadwiślański' during the flowering-maturing stage, but the water shortage in this period resulted in greater reduction of seed yield of 'Tim' cultivar than it did in that of 'Nadwiślański'.

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