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THE IMPACT OF VARIOUS PRIMARY TILLAGE METHODS ON THE YIELD COMPONENTS OF DRY BEAN

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ABSTRACT
In Hungary, dry bean (*Phaseolus vulgaris* L.) has been being popular as food and even as kitchen garden crop for centuries but currently only 20% of the annual domestic consumption is produced by the Hungarian agriculture, with the missing 80% coming from import. Improvement of production technology adapted to the new varieties of higher yield potential can contribute to the increase in domestic production. In our experiment, no significant differences could be found between the yield component and yield data of inversion (2.66 tons ha^{-1}) and non-inversion (2.62 tons ha^{-1}) tillage methods. Strip-tillage, however, resulted in higher values for almost all parameters compared to the other two methods. In the case of yield per plant, the difference was significant (24.35 vs. 18.33-18.57 grams ha^{-1}). As the plant density was significantly lower for strip-tillage, despite the significantly higher yield per plant, the yield per hectare results became the lowest (1.39 tons ha^{-1}) here. From the conditions detected after emergence, it was obvious that the harmonization of strip-tillage and sowing was not perfect. As the higher yield component and yield per plant data can be explained both by the lower plant density and the superiority of strip-tillage, the repetition of the experiment is essential.

Keywords: dry bean, strip-tillage, inversion tillage, non-inversion tillage, yield

INTRODUCTION

Dry bean (*Phaseolus vulgaris* L.) is an important food crop, usually being among the first 10 according to the size of its growth area in the world (33 million hectares in 2019; FAO, 2021). Although being popular as food and even as kitchen garden crop for centuries, its growth area has never been large in Hungary, in the last five years being between 1,415 and 1,713 hectares with a yield between 1.81 and 2.23 tons per hectare (KSH, 2021). Since the 1960's with even more than 30,000 hectares in some years, the growth area continuously decreased stepping below 1,000 hectares in 2006 (FAO, 2021). Currently, only 20% of the annual domestic consumption of dry beans is produced by the Hungarian agriculture, with the missing 80% coming from imports, mainly from China, Ethiopia and Slovakia. The primary aim of our EIP-AGRI project was to change this ratio in favour of domestic production. The possibility of this considerable modification is confirmed by the fact that the economic environment of the plant is promising: the domestic demand is high, varieties of higher yield potential (3 tons ha^{-1}) have appeared, and the buying-in prices are favourable - it can be concluded that a high turnover per ha can be achieved with this plant. The agri-environmental management programmes as well as the 'greening', a key element of the Common Agricultural Policy (CAP) also favour growing conditions, the cultivation of dry beans. In addition to the production environment, in recent years a trend in agriculture is - in addition to traditional arable crops - the search for alternative solutions with the possibility of growing intensive, high-turnover crops. Here, however, there is a significant risk of lacking a well-developed, widely known technology that can nuance

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growers' interest. To sum up, the dry bean is among the possible alternative crops with all pros and cons mentioned.
At present, dry bean production does not have a comprehensive, complex cultivation technology. The reason – and the consequence at the same time – is its very variable profitability, mainly due to the average yield which can be 30-40% lower than the potential due to the current procedures in use. In addition to the alternation of turnover, high cultivation costs are a significant problem, of which irrigation represents a significant share (SCHERER, 2019). Retaining moisture in the soil and protecting soil at the same time is a task that cannot be fulfilled with the current conventional technologies consisting of 4-5 tillage steps, in the course of which 8-20 mm of moisture per operation is removed from the soil. Conservation tillage, e.g. strip-tillage, however, can be efficiently used also in dry bean (OSORNO ET AL., 2019). On the other hand, to prevent *Fusarium* root rot, *Fusarium* wilt, *Rhizoctonia* root rot or *Sclerotinia* root rot infection, deep ploughing is recommended (LIEBENBERG, 2002). The higher-yielding dry bean varieties appeared recently also require new production strategies, even precision cultivation methods to fully utilize their genetic potential.
Here we report on the result of our experiment of comparing the effects of different primary tillage strategies on the yield of dry bean.

MATERIALS AND METHODS

The effects of three different primary tillage methods (inversion, non-inversion and strip-tillage) were compared in a farm-size experiment in Szeged, South-East Hungary. The three fields each were ca. 1.4 hectares in size. The soil analysis showed that the alluvial soil of the experimental area was mid-heavy, belonging to the loam and clay loam physical group. The humus content (1.6-2.4%) was poor/average, the AL-soluble P_2O_5 content (256-604 mg kg^{-1}) very good, while the AL-soluble K_2O content (271-491 mg kg^{-1}) between average and very good. The research was established in one growing season (2020), with the bean variety 'Marquis' of the 'Great Northern' type. Inversion tillage was done with a reversible plough at also 30 cm depth. Non-inversion tillage was performed with a field cultivator at 30 cm depth. For strip tillage, an Orthman 1tRIPr strip-till cultivator was used to prepare the soil for seeding in one pass, in a width of 25 cm and a depth of 30 cm along the rows. Sowing was performed on 30th April 2020 at a 70 cm row distance, with a seed rate of 250,000 ha^{-1}. The established plant density was determined on the 4th week. For the calculation of yield elements, five random samples were collected from each field on 15th August, each sample containing 5 plants being in full ripening. The following parameters were determined in laboratory: number of pods per plant, number of seeds per pod, thousand-grain-weight. The number of established plants per hectare was determined *in situ*, based on the number of plants per running meter in 23-26 sample areas per treatment.
For statistical analysis, analysis of variance and LSD as well as Tukey tests were done with the IBM SPSS Statistics software.

RESULTS

The yield components determined in the laboratory were statistically evaluated with the results summarized in *Table 1*. The values for the number of pods per plant, the seeds per pod and thousand grain weight did not show significant differences by ANOVA but each

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case the strip-tillage gave the highest results. The numbers of established plants, as calculated data, show significant differences in an indirect way: the number of plants per hectare for the strip-tillage was ca. 40% of those for the other two methods (*Table 1*).

Table 1. The effect of various tillage methods on the yield components of dry bean

Tillage method	**Yield component**			
	Pods per plant (No.)	Seeds per pod (No.)	Thousand grain weight (grams)	Established plants per hectare (No.)
Inversion	14.56±1.24a	3.84±0.14b	331.4±12.46c	143,000d
Non-inversion	14.92±1.14a	3.78±0.14b	322.4±8.09c	143,000d
Strip	17.88±1.92a	4.10±0.16b	336.6±20.47c	57,000e

The values show the mean and the standard error, the same letters mean no significant difference ($p \geq 0.05$).

Based on the pods per plant, seeds per pod and thousand grain weight values, the calculated yield per plant turned out to be significantly different between the strip-tillage (24.35±1.99 grams plant^{-1}) and the other two methods, strip-tillage giving the best result. The values for inversion (18.57±1.89 grams plant^{-1}) and non-inversion (18.33±1.61 grams plant^{-1}) tillage did not differ significantly, although, the inversion tillage showed higher values (*Figure 1*).

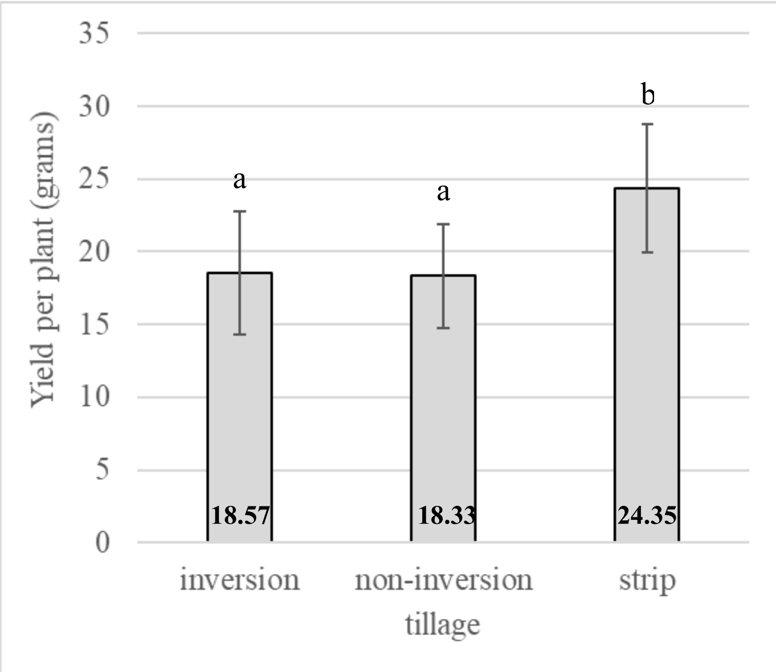

Figure 1. The effect of various tillage methods on the yield per dry bean plants
The bars represent standard deviation (n=5), the different letters indicate significant differences by Tukey test ($p<0.05$).

In the case of calculated yield per hectare, the tendencies changed. The yields for inversion (2.66±0.27 tons ha^{-1}) and non-inversion (2.62±0.23 tons ha^{-1}) tillage were not different significantly, while strip-tillage gave a significantly lower yield (1.39±0.11 tons ha^{-1}), ca. half the value of the other treatments (*Figure 2*).

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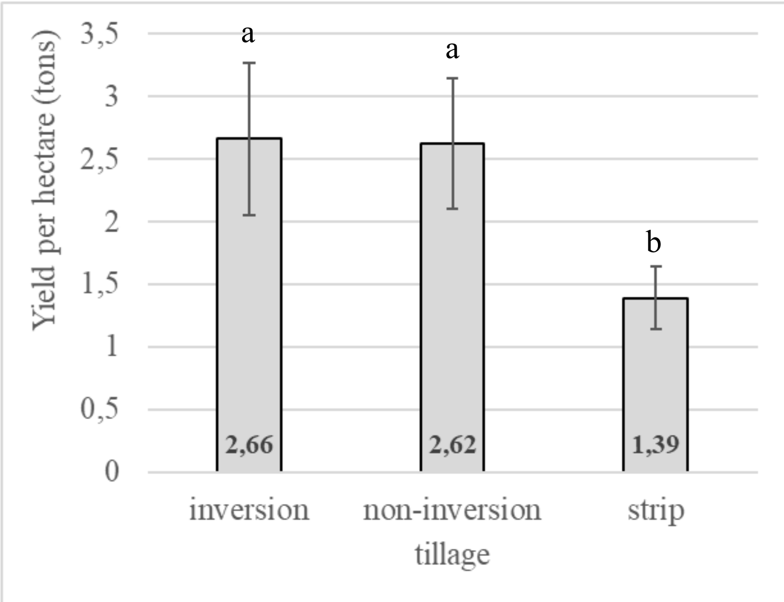

Figure 2. The effect of various tillage methods on the dry bean yield per hectare
The bars represent standard deviation (n=5), the different letters indicate significant differences by Tukey test ($p<0.05$).

DISCUSSION

In our experiment, there could be found no significant differences between the yield component and yield data of inversion and non-inversion tillage methods. Strip-tillage, however, resulted in significantly higher values for almost all parameters compared to the other two methods. As the plant density was significantly lower for strip-tillage, despite the significantly higher yield per plant, the yield per hectare results became the lowest. From the conditions detected at the establishment of plants, it seemed to be obvious that - in spite of the supposed to be proper setting of the driller – the harmonization of strip-tillage and sowing was not perfect. As the higher yield component and yield per plant data can be explained both by the lower plant density and the superiority of strip-tillage, the repetition of the experiment is essential.

In our experiment – to adapt the setup to the basic setting of the strip-till cultivator – 70 cm row spacing was applied throughout. In Hungary, a medium row spacing of 45-55 cm is usual (KÉSMÁRKI, 2005; SZABÓ, 2019) while in the US dry bean is sown at a variety of row distances between 53.34 and 76.2 cm (21-30 inch), the most common being 55.88 cm (22 inch) (OSORNO ET AL., 2019). A decrease from 76.2 cm (30 inch) to 38.1 cm (15 inch) row spacing could result in either no significant difference or considerable increase in yield (HALSALL, 2018). Cutting down on seed expenses and lower disease risk can be achieved by reducing seed rates. A 20 per cent reduction in seeding rates can result in minimal yield loss if the crop is planted early or on time (HALSALL, 2018). For 'Great Northern' type beans a population density of 173-198,000 per hectare is recommended in the US (OSORNO ET AL., 2019). In Hungary, an earlier cultivation guide recommends – depending on variety – a seed rate of 350-500,000 per hectare and calculates with a stand loss of 15-25% that means a final plant density of ca. 260-425,000 per hectare (KÉSMÁRKI, 2005). Similarly, a

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more recent work finds a final plant density of 250-300,000 per hectare being optimal (SZABÓ, 2019). In our experiment, after seeding at a rate of 250,000 per hectare the final plant density was between 57,000 and 143,000 per hectare, due to the high losses (>40%, data not shown) at emergence.

Our results show that dry bean can be successfully grown by using various primary tillage strategies as well as broader row spacing than usual. The equal utility of inversion and non-inversion tillage is confirmed by the non-significant results while the strip-tillage must be evaluated in a repeated experiment. Regarding row spacing, although higher row spacing results in lower yield, it can be compensated by the lower investment in the seed being relatively expensive in the case of dry bean varieties.

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