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THE EFFECTS OF TILLAGE METHODS AND PLANT DENSITY ON GROWTH, DEVELOPMENT AND YIELD OF SOYBEAN [*Glycine max* (L.) Merrill] GROWN UNDER MAIN AND SECOND CROPPING SYSTEM: II. GROWTH-DEVELOPMENT COMPONENT

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Abstract

The aim of this study was to compare tillage methods and plant density on growth, development and yield of soybean [Glycine max (L.) Merrill] grown under main and second cropping systems. The field experiments were carried out at the experimental area of Faculty of Agriculture, Dicle University during 2013 and 2014. The experiments were conducted as split-split plot design based on randomized complete blocks with two sowing dates (normal and late) as the main plot, three tillage methods (no-tillage, reduced and conventional) as sub-plot, and three between row spacing (35, 55 and 70 cm) sub-sub-plot factor. The experiments were performed in three replications and soybean cultivar Nova (MG III) was used. According to the two-year average results of the study, tillage methods had significant effects on dry weight and leaf area index in the R5 phase of the tillage treatment and reduced soil tillage by soil application, lower dry weight and leaf area index (LAI) value than conventional tillage method. Leaf growth rate (LGR) and leaf area ratio (LAR) were found significant between early planting (0.13 cm^2/cm^2/ day, 0.15 cm^2/g) and late planting (0.09 cm^2/cm^2/day, 0.12 cm^2/g).

***Key words**: soybean, sowing time, tillage, plant density, yield, growth.*

INTRODUCTION

Due to the limited availability of arable land in the world, the nutritional deficiencies associated with the growing population are required to meet by the increase either in yield or in the unit area. For this reason, producers need alternative agricultural practices that can provide the highest yield potential with lower production costs. By means of this, while high yielding and and high quality varieties are developed using breeding studies, determination of effect of agronomic studies such as irrigation, fertilization, sowing time, tillage and sowing density plant growth and development intensively continue. Determination of the optimal number of plants and the optimal tillage methods from agricultural practices has been the subject of prior research in recent years (Peterson, Higley, 2001).

When main crop soybean cultivation is compared with second crop soybean the potential benefits of soybean can be counted as follows: intensive use of resources, reduction of soil erosion, reduction of production cost, and increase of income level of producers (Sanford et al., 1986).

Tillage methods in crop production affect plant growth and development. As a matter of fact, Sürek (2004) stated that protected soil tillage practices can delay or reduce the severity of drought stress in the second crop of soya agriculture. Besides, preplant wastes are one of the important components of reduced soil tillage method. They just not add required nutrients to the soil (Erenstein, 2003), but also help soil temperature to be balanced via reducing evaporation (Greb, 1966; Wilhelm et al., 1989) and consequently, affects crop yield (Biamah, 2005).

For most soils, plant residues increase the infiltration of water in the root zone (Bruce et al., 1987; Dick et al., 1987), reducing water surface runoff and soil loss, thereby providing favorable conditions for soil treatment and thus increasing product yield. When reduced or no tilling methods can be used as alternative methods to conventional soil treatment, since planting time are predated, second crop can expand the planting fields.

The growth and development of a plant in the agricultural ecosystem is affected by agricultural practices such as number of rows and number of plants. Different row spacing and plant density affects plant lighting, photosynthesis rate and consequently plant productivity. Narrow row spacing in grain plants results in increased light uptake during the first developmental period of the plant and may lead to higher seed yield compared to standard row spacing. Moreover, the ability of cultivated plants to compete with weeds in agricultural ecosystems depends, in part, on the plant growth rate. Plants that are capable of forming canopy from the first developmental period, such as soybean, are able to suppress the weed population more than other cultivated plants. Leaf area index, canopy formation rate and plant height significantly affect the competitiveness and tolerance of cultivated plants against weeds (Peterson, Higley, 2001).

Although our country, especially the Mediterranean, Aegean and Southeastern Anatolian Regions, have suitable ecological conditions for soybean production, unfortunately the plantation area and the production amount have remained very low. Therefore, in this study, it was aimed at determination of effects of different tillage methods on soybean growth and development in case of cultivation of main crop and second crop soybean using proper row spacing.

MATERIALS AND METHODS

The study was carried out at experimental area of Field Crops Department, Faculty of Agriculture, Dicle University, Diyarbakir located in South East Anatolian Region of Turkey in 2013 and 2014. The region has a warm climate in summer, and the mean annual rainfall is around 450 mm, most of which fall in a major cropping season which extends from November to June (Anonymous, 1990). Experimental soil has a heavy built (fine textured), it is poor in terms of organic matter and phosphorus with medium lime and moderate alkaline reaction and high cation exchange capacity no salt (Anonymous, 1995). The treatments were replicated three times in split-split plot based on randomized complete block design with sowing time (early and late) in the main plots, tillage systems (no-tillage, reduced tillage and conventional tillage) in the sub-plots and plant density of 35 x 5 cm, 55 x 5 cm and 70 x 5 cm with 571,400, 363,600 and 285,700 plants ha^{-1} in the sub-sub-plots. Conventional tillage (plough + disc harrow), reduced tillage (cultivator) and no-tillage (without any tillage) treatments were involved before sowing. On the basis of soil analysis, the crop was fertilized with 100 kg N and 100 kg P_2O_5 ha^{-1} applied as basal dose in the form of 20-20-0 fertilizer prior to sowing. In addition, top dressing nitrogen was provided at the time of full flowering stage at the rate of 100 kg ha^{-1} as ammonium nitrate (33% N) for all plots. Weeds were controlled by both Trifluralin (2.5 l ha^{-1}) as pre plant and by hand as needed. The field was uniformly irrigated at 10-days intervals until harvest period using overhead sprinklers. Soybean cultivar Nova (MG III) was sown as early sowing on May and late sowing on June. At R8 (Fehr, Caviness, 1977), all plots were harvested from two central rows in mid-September and in mid-October (for early and late sowing, respectively) and threshed for seed yield (kg ha^{-1}). In both years, the seeds from each plot were taken after harvest for determining oil and protein content of seeds.

Data was subjected to an analysis of variance (ANOVA) using a statistical software package (JMP version 5.0.1a). Least significant difference (Tukey's HSD test) was used to compare treatment means at P=0.05.

Plant Dry Weight (g $plant^{-1}$)

In two different developmental periods (flowering-R1 and seedling-R5) as a mean of 5 plants in each plot; It was dried and weighed at 80°C until it reached constant weight and determined in grams.

Leaf Area İndex (cm^2 cm^{-2})

It was calculated according to the following formula, developed by Radford (1967), recommended by the Board (2000), using the WINFOLIA leaf area program as an average of 5 plants in each of the two different growth stages (flowering-R1 and seeding-R5):

$$LAI = \frac{\text{Total plant leaf area } (cm^2)}{\text{Total area covered by the plant } (cm^2)}$$

Plant Growth Rate ($g/m^2/day$)

It was calculated according to the following formula, Board (2000) and developed by Radford (1967):

$$PGR = \frac{W_2 - W_1}{T_2 - T_1}$$

W_1: $T_{1\,(time)}$ Dry weight of plants in T_1 (g $plant^{-1}$);
W_2: $T_{2(time)}$ Dry weight of plants in T_2 (g $plant^{-1}$);

T_1: 1. When dry matter is detected during development (day);
T_2: 2. When dry matter is detected during development (day).

Leaf Growth Rate (cm^2/m^2/day)
It was calculated according to the following formula, Board (2000) and developed by Radford (1967):

$$LGR = \frac{LA\dot{I}_2 - LA\dot{I}_1}{T_2 - T_1}$$

$LA\dot{I}_1$: $t_{1(time)}$ Leaf Area Index ($cm^2\ cm^{-2}$);
$LA\dot{I}_2$: $t_{2(time)}$ Leaf Area Index ($cm^2\ cm^{-2}$);
T_1: 1. When the leaf area index is determined during development (day);
T_2: 2. When the leaf area index is determined during development (day).

Leaf Area Rate (cm^2/g)
It was calculated according to the following formula, Board (2000) and developed by Radford (1967):

$$LAR = \frac{(LA_2 - LA_1)\ (\log_e W_2 - \log_e W_1)]}{[(\log_e LA_2 - \log_e LA_1)\ (W_2 - W_1)]}$$

LA: Leaf Area (cm^2);
W: Plant Dry Weight (g).

Relative Growth Rate (g/g/day)
According to the following formula proposed by Gardner et al. (1985):

$$RGR = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

W_1: $t_{1(time)}$ Plant Dry Weight (g $plant^{-1}$);
W_2: $t_{2(time)}$ Plant Dry Weight (g $plant^{-1}$);
T_1: 1. When dry metal is detected during development (day);
T_2: 2. When dry metal is detected during development (day).

Net Assimilation Rate (g m^{-2} day^{-1})
Gardner et al. (1985) proposed the following formula:

$$NAO = PGR\ X\ \frac{\log_e L_2 - \log_e L_1}{T_2 - T_1}$$

PGR: Plant Growth Rate
L_1: $T_{1(time)}$ Leaf Area (m^2);
L_2: $T_{2(time)}$ Leaf Area (m^2).

RESULTS AND DISCUSIONS

According to the results of the experiment the two-year average values showing the effects of tillage methods and plant density on the yield and quality characteristics of soybean grown as the main and double-crop soybeans are given in the Table 2.

1. Plant dry weight at the first flowering period (R1) (g/plant)
The effect of planting time on plant dry weight was found significant, according to the effect obtained on the dry weight of the plant in flowering period (R1). In terms of the two-year average, while the plant dry weight was 16.02 g in early planting, when planting delay, a significant decrease in plant dry weight was observed (13.28 g). No significant difference between soil treatments was obtained (Table 1). In terms of the two-year average, it varied between 14.34-14.98 g (Al-Darby, Lowery, 1987); the amount of dry matter per plant is lower in no tillage than conventional or reduce tillage method. Similar findings were also obtained by researcher Janovicek (1991), indicating that the dry matter accumulation in the soilless system is lower than in the plow and the autumn. While there was a significant difference between the practices in terms of plant density, as the plant density increased with respect to the two-year average values, a decrease in plant dry weight was observed in the first flowering period. The highest value was obtained from a plant density of 70 x 5 cm (16.31 g/plant).

2. The plant dry weight in the seedling period (R5) (g $plant^{-1}$)
The plant dry weight was found 32.38 g $plant^{-1}$ in early planting, while the plant dry weight was reduced to 28.91 g $plant^{-1}$ when the planting date was delayed, according to the obtained value for the effect on plant dry weight at the seeding period. The effect of the tillage method on the plant dry weight was found significant. The plant dry weight varied between 29.73-31.38 g $plant^{-1}$ and the highest plant dry weight was obtained from conventional tillage treatment (31.38 g/plant).
In this regard, Yusuf et al. (1999) found that dry matter weights of total plant, stem, leaf and fruit of plants grown in the conventional tillage method were about 15-20% higher in the early

stages of development than those without soil treatment, whereas plants were grown in the R5-R6 stage. As a result of the reduction of this difference in reach, the seed yield, oil and protein ratio can be compensated. Similar findings were also obtained by Janovicek (1991), indicating that the dry matter accumulation in the soilless system is lower than in the plow and the autumn. The effect of plant density on the dry weight of the plant during seedling period was significant.

The plant dry weight varied between 28.83-32.76 g/plant, and as the plant density decreased, the plant dry weight gain was increased and the highest dry weight was obtained from the plant density of 70 x 5 cm (32.76 g/plant). Rahman et al. (2013) found different values in their study.

3. Leaf area index in the first flowering period (R1) (cm^2 cm^{-2})

There was not found effect on the leaf area index of sowing time, it was 2.29 cm^2 cm^{-2} in early sowing and 1.79 cm^2 cm^{-2} in late sowing. The leaf area index is defined as the green leaf area per unit area and is closely related to the seed yield and should be in the range of 3.5-4.0 in order to achieve the light uptake of 95% required for optimum seed yield (Board and Harville, 1992).

Canopy is an important factor determining the yield potential in the lineage. There is a significant relationship between total dry matter accumulation and plant growth rate and seed yield, and it is noted that these characteristics are strongly related to the plant canopy (De Bruin and Pedersen, 2009). Our findings were similar to those of Hu (2013) and Muhammad et al. (2009) and contrary to the results of Pedersen and Lauer (2004).

The effect of tillage method on leaf area index was not observed and ranged from 1.96-2.12 cm^2/cm^2. However, Pedersen and Lauer (2004) found that leaf area index values obtained from no tillage treatment were higher than those from conventional tillage method.

It was determined that plant density are significantly effective on the leaf area index. While the highest leaf area index value was obtained from the plant density of 35 x 5 cm (2.48 cm^2/cm^2), no difference was observed between the plant density of 35 x 5 cm and 70 x 5 cm. As can be seen from this, the leaf area index value increases as the plant density increases. In soybean, grown at low plant population density, due to less light intake during the flowering period reduction of leaf area and consequently decrease in plant growth rate took place (Andrade, 1995).

4. Leaf area index in seed growth period (R5) (cm^2 cm^{-2})

The effect of sowing time on the leaf area index was significant in the seeding period and was 5.02 cm^2 cm^{-2} in early sowing and 3.75 cm^2 cm^{-2} in late sowing. Kandil et al. (2013), similar results were obtained, and the effect of sowing time on the leaf area index was found to be significant. In addition, Pedersen and Lauer (2004) found that leaf area index decreased with the delay of planting. The effect of soil treatment on leaf area index was found significant. Although there is no difference between the effects on the leaf area index and no-tillage method (4.09 cm^2 cm^{-2}) and reduced tillage method (4.35 cm^2 cm^{-2}), the higher leaf area index was obtained (4.72 cm^2 cm^{-2}) in the conventional tillage method.

Pedersen and Lauer (2004) found that leaf area index value obtained from no-tillage method was higher than conventional tillage method.

Significant differences were observed in the plant density in terms of the leaf area index. The highest leaf area index value (5.19 cm^2 cm^{-2}) was obtained from the 35 x 5 cm plant density, while no difference was observed between the 55 x 5 cm plant density and the 70 x 5 cm plant density (3.88 cm^2 cm^{-2} and 4.09 cm^2 cm^{-2}, respectively).

In the study conducted by Rahman and Hossain (2011), the plant density indicated that the residual leaf area index value was increased, and as a result, my work did not produce similar results.

5. Plant Growth Rate (g m^{-2} day^{-1})

The effect on the growth rate of sowing time was found no significant and it was obtained (as 8.18 g m^{-2} day^{-1} in early planting and 7.18 g m^{-2} day^{-1} in late planting) Muhammad et al. (2009) have reported that plant growth rate is regressed when planting date is late, and the results are similar to our findings. However, Pedersen and Lauer (2004) found that the results of our study were inconsistent with our findings, indicating that plant growth rate was higher in early sowing.

The plant growth rate varied between 7.57-8.52 g m^{-2} day^{-1} and the plant growth rate value obtained from conventional tillage method was found to be the highest (8.52 g m^{-2} day^{-1}), while the effect of soil treatment on plant growth rate was not significant.

As a result of Pedersen and Lauer (2004)'s study, we obtained different findings from our study and stated that the value of plant growth rate in the conventional tillage method is lower than the value of the plant growth rate obtained in the no-tillage method.

The effects of plant density on plant growth rate were considered negligible. Plant growth rate values ranged from 7.86 to 8.22 g $m^{-2}day^{-1}$. While Egli and Bruening (2000) indicated that plants at significant plant populations experienced significant decreases in plant growth rate as a result of shading of each other, Rahman and Hossain (2011) and Cox and Cherney (2008) reported that plant density increased by an increase in plant growth rate.

6. Leaf growth rate (cm^2 cm^{-2} day^{-1})

The effect of sowing time on leaf growth rate was found to be significant, according to the effect obtained on leaf growth rate. Leaf growth rate was 0.09 cm^2 cm^{-2} day^{-1} in late sowing time application and 0.13 cm^2/cm^2/day in early sowing.

The effect of soil treatment on leaf growth rate was insignificant and leaf growth rate varied between 0.10-0.12 cm^2 cm^{-2} day^{-1}. However, in Pedersen and Lauer (2004), the leaf growth rate of conventional tillage application was lower than the leaf growth rate obtained without soil treatment and they had different results from our study. The highest growth rate was found to be 35x5 plant density (0.13 cm^2 cm^{-2} day^{-1}), whereas no significant difference was observed between 55 x 5 cm and 70 x 5 cm plant density (0.10 and 0.11 cm^2 cm^{-2} day^{-1}).

7. Leaf area rate (cm^2 g^{-1})

The effect of planting time on the leaf area ratio was found significant. When early planting was 0.15 cm^2 g^{-1}, leaf area ratio decreased to 0.12 cm^2 $g^{-1}$when planting date was delayed. The effects of the tillage method on leaf area ratio were insignificant compared to the two-year average. Leaf area ratio values varied between 0.13-0.15 cm^2 g^{-1}).

The effect of plant density on leaf area ratio was found to be significant and there was no significant difference between plant density of 55 x 5 cm (0.12 cm^2/g) and 70 x 5 cm (0.13 cm^2/g) and the highest leaf area ratio was obtained from 35 x 5 cm plant density (0.16 cm^2/g).

8. Relative growth rate (g g^{-1} day^{-1})

When the relative growth rate of early planting was 0.031 g g^{-1} day^{-1} and the planting date was delayed, this ratio was 0.038 g/g/day. The effect of the soil treatment on the relative growth rate has been reached as a result. The effect of plant density on the relative growth rate was found to be significant, with an increase in the relative growth rate (0.035 g g^{-1} day^{-1}) as the plant density increased.

According to this data, the net assimilation rate is decreasing as the plant development stage progresses, and it is estimated that this decrease is due to the fact that the plants are not shaded each other due to the increase of the leaf area index (Addo-Quaye et al., 2011).

9. Net assimilation rate (g m^{-2} day^{-1})

Indeed, Watson (1958) notes that there is a very strong inverse relationship between net assimilation rate and leaf area index. The effects of sowing time on the net assimilation rate were no-significant. The net assimilation rate increased with the delay of the sowing time and the highest values were obtained from the cultivations carried out on June 5 (Kandil et al., 2013).

The effects on the net assimilation rate of the tillage methods were nosignificant compared to the two-year average and the net assimilation rate varied between 2.77-3.12 g m^{-2} day^{-1}).

The effect of plant density on net assimilation rate was found to be significant. There was no significant difference between application of 55 x 5 cm plant density (3.22 g m^{-2} day^{-1}) and 70 x 5 cm plant density (3.27 g m^{-2} day^{-1}) and net assimilation rate was higher than application of 35 x 5 cm plant density (2.27 g m^{-2} day^{-1}). Similar results were obtained from studies conducted by Carpenter and Board (1997), indicating that plants grown at low plant frequencies had a higher rate of light utilization and higher photosynthetic rate than those grown at higher plant frequencies.

CONCLUSIONS

Data collected in the average results of two study years indicate that early sowing time were found significant on Plant dry weight [(PDW (R1) and (R5)], leaf area ındex [LAI (R5)], leaf growth rate (LGR) and leaf area rate (LAR) than late sowing time. Tillage methods had significant effects on dry weight and leaf area index in the R5 phase of the tillage treatment and reduced soil tillage by soil application, lower dry weight and leaf area index (LAI) value than conventional tillage method. The highest Plant dry weight (PDW) and net assimilation rate (NAR) were obtained in the lowest plant density otherwise the highest leaf area ındex (LAI), leaf growth rate (LGR), leaf area rate (LAR) and relative growth rate (RGR) were found on 35x5 cm row spacing.

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Table 1. Analysis of variance (mean square) for Plant dry weight at the first flowering period (R1) (g plant^{-1}). The plant dry weight in the seedling period (R5) (g plant^{-1}), Leaf area index in the first flowering period (R1) (cm^2 cm^{-2}), Leaf area index in seed growth period (R5) (cm^2 cm^{-2}), Plant Growth Rate (g m^{-2} day^{-1}), Leaf area rate (cm^2 g^{-1}), Relative growth rate (g g^{-1} day^{-1}) and Net assimilation rate (g m^{-2} day^{-1}) at different tillage systems and plant density of soybean grown under main and double-cropping systems

Practices	DF	PDW (R1) (g plant^{-1})	PDW (R5) (g plant^{-1})	LAI (R1) (cm^2 cm^{-2})	LAI (R5) (cm^2 cm^{-2})	PGR (g m^{-2} day^{-1})	LGR (cm^2 cm^{-2} day^{-1})	LAR (cm^2 g^{-1})	RGR (g g^{-1} day^{-1})	NAR (g m^{-2} day^{-1})
Sowing Time (S)	1	202.81*	326.21*	6.91	43.65*	3.65	0.03*	0.02*	0.0004	8.12
Tillage (T)	2	3.81	24.13	0.58	3.57*	8.43	0.005	0.002	0.0001	1.17
Plant Spacing (PS)	2	97.70**	141.57	5.09*	17.76**	1.39	0.009**	0.02**	0.0002*	11.47*
S x T	2	30.16**	42.81**	0.58	4.09	5.67*	0.007*	0.01*	0.0002*	0.72
S x PS	2	9.65	3.30	0.07	0.06	1.23	0.0006	0.001	0.0004	0.49
T x PS	4	6.54	12.01	0.78*	1.78	4.95*	0.004	0.009*	0.00001	1.96*
S x T x PS	4	10.39*	11.73	0.49	1.93	1.89	0.003	0.009*	0.00027	1.04

PDW: Plant dry weight; R1: First flowering period; R5: Seed growth period; PGR: Plant Growth Rate; LGR: Leaf Growth Rate; LAR: Leaf Area Rate; RGR: Relative Growth Rate; NAR: Net Assimilation Rate.

Table 2. Effect of tillage and plant density on Plant dry weight at the first flowering period (R1) (g plant^{-1}). The plant dry weight in the seedling period (R5) (g plant^{-1}), Leaf area index in the first flowering period (R1) (cm^2 cm^{-2}), Leaf area index in seed growth period (R5) (cm^2 cm^{-2}), Plant Growth Rate (g m^{-2} day^{-1}), Leaf area rate (cm^2 g^{-1}), Relative growth rate (g g^{-1} day^{-1}) and Net assimilation rate (g m^{-2} day^{-1}) at different tillage systems and plant density of soybean grown under main and double-cropping systems

Treatments	PDW (R1) (g plant^{-1})	PDW (R5) (g plant^{-1})	LAI (R1) (cm^2 cm^{-2})	LAI (R5) (cm^2 cm^{-2})	PGR (g m^{-2} day^{-1})	LGR (cm^2 cm^{-2} day^{-1})	LAR (cm^2 g^{-1})	RGR (g g^{-1} day^{-1})	NAR (g m^{-2} day^{-1})
Sowing Time									
Early	16.02 A	32.38 A	2.29	5.02A	8.18	0.13 A	0.15 A	0.031	2.65
Late	13.28 B	28.91 B	1.79	3.75 B	7.81	0.09 B	0.12 B	0.038	3.19
LSD (5%)	1.47	1.96	ns	0.77	ns	0.01	0.02	ns	ns
Tillage									
No-Tillage	14.98	30.79 AB	2.12	4.09 B	7.90	0.10	0.13	0.03	3.12
Reduced Tillage	14.62	29.77 B	2.05	4.35 B	7.57	0.10	0.14	0.03	2.77
Conventional Tillage	14.34	31.38 A	1.96	4.72 A	8.52	0.12	0.15	0.03	2.87
LSD (5%)	ns	1.29	ns	0.31	ns	ns	ns	ns	ns
Plant Density									
35x5 cm	13.01 C	28.83 B	2.48 A	5.19 A	7.90	0.13 A	0.16 A	0.035 A	2.27 B
55x5 cm	14.62 B	30.35 B	1.80 B	3.88 B	7.86	0.10 B	0.12 B	0.035 AB	3.22 A
70x5 cm	16.31 A	32.76 A	1.81 B	4.09 B	8.22	0.11 B	0.13 B	0.030 B	3.27 A
LSD (5%)	1.17	1.80	0.35	0.44	ns	0.01	0.01	0.003	0.55
Average	14.64	30.64	2.04	4.38	7.99	0.13	0.13	0.03	2.92

Columns marked with different letters are significantly different at $P \leq 0.05$; ns: no-significant; PDW: Plant Dry Weight; R1: First Flowering Period; R5: Seed Growth Period; PGR: Plant Growth Rate; LGR: Leaf Growth Rate; LAR: Leaf Area Rate; RGR: Relative Growth Rate; NAR: Net Assimilation Rate

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