

## INFLUENCE OF TANK MIXTURES OF SOIL-APPLIED HERBICIDES ON NITROGEN-FIXING NODULES, WEED INFESTATION AND CHICKPEA YIELD

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*We found that the studied tank mixtures of modern soil-applied herbicides in chickpea crops did not cause inhibition of plant growth and development. No negative effect of tank mixtures of soil-applied herbicides on the fresh weight of nitrogen-fixing nodules on the chickpea root at pod filling stage was detected. It was determined that fresh weight of nitrogen-fixing nodules per chickpea plant (1.36 g) increased the most when using the tank mixture of Tizer, 2.0 l/ha + Advokat, 0.5 l/ha. In the variant of application of the herbicide mixture of Tizer, 2.0 l/ha + Panda, 3.5 l/ha, a significant increase in the fresh weight of one chickpea plant (by 87 %) was noticed.*

*Precipitation, which fell immediately after the application of tank mixtures of soil-applied herbicides, increased herbicide efficiency. The phytotoxic effect of the most tank mixtures in chickpea crop was larger on biennial dicotyledonous weeds than annual grasses. At the first accounting, it was found that the number of annual grasses and biennial dicotyledonous weeds in chickpea crops was the best controlled with the tank mixture of herbicides Herb 900, 2.0 l/ha + Kapral, 2.0 l/ha (77 and 93 %, respectively), at the second accounting – Tizer, 2.0 l/ha + Panda, 3.5 l/ha (87 and 91 %, respectively). At the end of the chickpea growing season, the fresh weight of annual grasses was most reduced with the tank mixture Tizer, 2.0 l/ha + Dual Gold 960 EC, 1.6 l/ha (93 %), and fresh weight of biennial dicotyledonous weeds – by applying Tizer, 2.0 l/ha + Panda, 3.5 l/ha (95 %).*

*The total fresh weight of annual grasses and biennial dicotyledonous weeds in chickpea crops was decreased in large measure under the phytotoxic effect of the tank mixtures of herbicides Tizer, 2.0 l/ha + Panda, 3.5 l/ha (by 92 %). When applying the combination of herbicides such as Tizer, 2.0 l/ha + Premium Gold, 3.0 l/ha, and Tizer, 2.0 l/ha + Panda, 3.5 l/ha in chickpea crops, the largest grain yield gain was 0.15 and 0.12 t/ha, respectively.*

**Key words:** chickpea, soil-applied herbicides, nitrogen-fixing nodules, weeds, yield.

Chickpea (*Cicer arietinum* L.) is a valuable food and fodder grain legume crop. Its seeds contain 25–30 % protein, 50–60 % nitrogen-free extracts, 4–5 % fat, 3–5 % ash. Grain products of white-seeded varieties of chickpeas are used to make canned food, confectionery, coffee surrogates, etc. The dark-seeded varieties of chickpeas used for animal feed [1]. Chickpeas are a good predecessor for agricultural crops [1–2].

In recent years, our country has achieved significant success in the development of collectible samples and different varieties of chickpeas for food production and in the selection for chickpea yield [3–4]. At the same time, the level of chickpea yield depends on many factors. In particular, the weeds in chickpea crops significantly affect both chickpeas yield and quality [5]. In this regard, the issue of protection of this grain legume crop from weeds is becoming relevant.

According to data of V. S. Zadorozhnyi

and co-authors, weeding chickpea crops should be carried out when the number of annual weeds is 10 per 1 m<sup>2</sup>, and this measure should be completed within 20 days after sprout emergence of chickpea [6]. This problem is successfully solved with the soil-applied herbicides. Currently, there are soil-applied herbicides based on active ingredients: 330 g/l pendimethalin (Panda and Trump), as well as 250 g/l fluorochloridone (Racer), which are officially approved for chickpea crops in Ukraine. [7]. However, our country accumulated long-term experience of application of a whole range of soil-applied herbicides on the chickpeas areas. In particular, we studied the efficiency of soil-applied herbicides such as Pulsar 40 (40 g/l imazamox) [5], Stomp 330 EC (330 g/l pendimethalin), Harness (900 g/l acetochlor), Frontier Optima (720 g/l dimethenamid-P) [6], Trophy 90 EC (900 g/l acetochlor) [8-9], Pivot (100 g/l imazethapyr), Racer [9].

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However, it is impossible to completely solve the problem of chickpea protection from annual grasses and dicotyledonous weeds by means of the application of these herbicides. In this case, more efficiency is provided with tank mixtures. Thus, our previous research has shown that it is possible to simultaneously control the development and spread of annual grasses and biennial dicotyledonous weeds in chickpea crops by the application of a tank mixture of Herb 900 (1.25 l/ha) + Serp (0.375 l/ha) [10]. It was necessary to compare the phytotoxic effect on the above weed groups this tank mixture (as a standard) and other combinations of soil-applied herbicides.

**Aim.** We should find out the influence of tank mixtures of modern soil-applied herbicides on the number of annual grasses and biennial dicotyledonous weeds in chickpea crops, and how they effect on the formation of fresh weight of both nitrogen-fixing nodules and plants of this grain legume crop, as well as its yield.

**Materials and Methods.** The research was conducted during 2016–2018 in the eastern For-

est-Steppe of Ukraine. Soil was typical heavy loam chernozem. Predecessor – spring barley. The improved fall plowing was the main way to prepare soil for sowing. Pre-sowing tillage consisted in early spring harrowing and one cultivation. Chickpea seeds (Triumf variety) with a row spacing of 15 cm were used for sowing. Immediately after sowing, the soil was rolling with followed application of pre-emergence herbicide tank mixtures (without incorporation into the soil). The field trial scheme included the following herbicides: Herb 900 (900 g/l acetochlor), Serp (100 g/l imazethapyr), Kapral (500 g/l prometryn), Advokat (600 g/l metribuzin), Tizer (720 g/l propisochlor), Premium Gold (312.5 g/l S-metolachlor + 187.5 g/l terbuthylazine), Panda, Stels (250 g/l fluorochloridone), Dual Gold 960 EC (960 g/l S - metolachlor) (Table 1). Tank herbicide mixtures with application rate of 300 l/ha were applied with a knapsack sprayer. Control variant was with natural weed infestation (without the application of herbicides). The accounting area of plot – 36 m<sup>2</sup>, replication – three times.

**1. Fresh weight of nitrogen-fixing nodules and chickpea plants at the podding stage depending on the action of tank mixtures of soil-applied herbicides (average for 2016–2018)**

Variant	Fresh weight, g	
	of nodules per a chickpea plant	of a chickpea plant
Control	0.65	16.7
Herb 900, 1.25 l/ha + Serp, 0.375 l/ha (standard)	0.90	23.4
Herb 900, 2.0 l/ha + Kapral, 2.0 l/ha	1.12	29.6
Herb 900, 2.0 l/ha + Advokat, 0.3 l/ha	0.81	23.0
Tizer, 2.0 l/ha + Kapral, 2.0 l/ha	0.88	24.8
Tizer, 2.0 l/ha + Advokat, 0.5 l/ha	1.36	30.4
Tizer, 2.0 l/ha + Premium Gold, 3.0 l/ha	0.97	27.9
Tizer, 2.0 l/ha + Panda, 3.5 l/ha	0.93	31.2
Tizer, 2.0 l/ha + Stels, 2.0 l/ha	1.14	29.1
Tizer, 2.0 l/ha + Dual Gold 960 EC, 1.6 l/ha	1.01	23.5
LSD <sub>05</sub>	0.39	8.9

Weeds on chickpea plots were counted twice: at the beginning of the growing season (30 days after herbicide application) by the quantitative method; and at the end of the growing season by the quantitative-weight method. Fresh weight of nitrogen-fixing nodules and chickpea plants was determined by weight method in the podding stage. The yield was accounted by the method of continuous threshing the accounting plot by the Sampo-130 combine.

**Results.** It was established by long-term observations that the studied tank mixtures of

soil-applied herbicides did not inhibit the growth processes in chickpea plants. Only in 2016, short-term phytotoxic inhibition of plants was observed in the standard tank mixture [10].

It was found that the tank mixtures of soil-applied herbicides compared to the standard did not have negative effect on the fresh weight of nitrogen-fixing nodules on the root system of chickpeas (in the podding stage). Over three years of research, the largest fresh weight of nodules per a chickpea plant was when applying a tank mixture of Tizer + Advokat; also this in

indicator (in comparison with other variants) was higher at the application of such tank mixtures of Herb 900 + Kapral and Tizer + Stels herbicides.

It was found that the fresh weight of a chickpea plant increased compared to the control when applying tank mixtures of Herb 900 + Kapral (by 77 %), Tizer + Advokat (by 82 %), Tizer + Premium Gold (by 67 %), Tizer + Panda (by 87 %) and Tizer + Stels (by 74 %) herbicides.

It was found that the efficiency of tank mixtures of soil herbicides for weed control in chickpea crops depended on the precipitation amount during the first period after their application. In 2016, during the first ten days after the herbicide application, precipitation was 46.6 mm, and in 2018 – 5.0 mm; the average efficiency of tank mixtures of herbicides against of annual grasses and biennial dicotyledonous weeds at the first accounting was 90 and 79 %, at the second – 94 and 87 %, respectively. It

was no precipitation during the first ten days after the herbicide application in 2017. The average efficiency of tank mixtures in controlling of annual grasses and biennial dicotyledonous weeds at the first accounting was 73, and second – 76 %. On average, in three years of research in the first and second accounting, tank mixtures of soil herbicides better controlled the number of biennial dicotyledonous weeds (by 90 and 84 %, respectively) than annual cereal weeds (by 73 and 79 %, respectively).

Most of the tank mixtures of soil-applied herbicides compared to the standard significantly affected the total number of annual grasses and biennial dicotyledonous weeds on chickpea plots. When the first accounting was carried out, the tank mixture of Herb 900 + Kapral was the most effective against annual grasses and biennial dicotyledonous weeds (77 and 93 %, respectively), and at the second accounting – Tizer + Panda (87 and 91 %, respectively).

**2. The number of weeds in chickpea crops depending on the tank mixtures of soil-applied herbicides (average for 2016-2018)**

Variant	Annual grasses	Biennial dicotyledonous	Perennial dicotyledonous	Total
at the beginning of the growing season, pcs/m <sup>2</sup>				
Control	732.5	160.3	25.1	917.9
Herb 900, 1.25 l/ha + Serp, 0.375 l/ha (standard)	293.1	16.0	21.4	330.5
Herb 900, 2.0 l/ha + Kapral, 2.0 l/ha	165.8	11.5	27.1	204.4
Herb 900, 2.0 l/ha + Advokat, 0.3 l/ha	211.5	16.8	27.9	256.2
Tizer, 2.0 l/ha + Kapral, 2.0 l/ha	243.8	17.3	33.8	294.9
Tizer, 2.0 l/ha + Advokat, 0.5 l/ha	242.5	21.7	24.2	288.4
Tizer, 2.0 l/ha + Premium Gold, 3.0 l/ha	204.4	15.0	14.7	234.1
Tizer, 2.0 l/ha + Panda, 3.5 l/ha	200.4	17.5	15.5	233.4
Tizer, 2.0 l/ha + Stels, 2.0 l/ha	268.0	18.4	16.9	303.3
Tizer, 2.0 l/ha + Dual Gold 960 EC, 1.6 l/ha	176.9	28.6	34.9	240.4
LSD <sub>05</sub>	298.7	50.6	21.8	342.7
at the end of the growing season, pcs/m <sup>2</sup>				
Control	485.9	136.5	21.9	644.3
Herb 900, 1.25 l/ha + Serp, 0.375 l/ha (standard)	108.3	24.1	29.2	161.6
Herb 900, 2.0 l/ha + Kapral, 2.0 l/ha	70.2	23.0	29.1	122.3
Herb 900, 2.0 l/ha + Advokat, 0.3 l/ha	86.0	16.9	28.1	131.0
Tizer, 2.0 l/ha + Kapral, 2.0 l/ha	128.2	24.0	26.5	178.7
Tizer, 2.0 l/ha + Advokat, 0.5 l/ha	125.1	23.5	30.8	179.4
Tizer, 2.0 l/ha + Premium Gold, 3.0 l/ha	90.2	20.4	26.8	137.4
Tizer, 2.0 l/ha + Panda, 3.5 l/ha	62.2	12.4	24.4	99.0
Tizer, 2.0 l/ha + Stels, 2.0 l/ha	108.1	15.6	17.1	140.8
Tizer, 2.0 l/ha + Dual Gold 960 EC, 1.6 l/ha	66.8	31.2	30.0	128.0
LSD <sub>05</sub>	184.3	42.8	21.6	222.2

The biennial dicotyledonous weeds were not affected by these soil-applied herbicides. At the first and second accounting practices, it was found that the lowest total number of weeds was

when applying tank mixtures of Herb 900 + Kapral and Tizer + Panda herbicides. All tank mixtures reduced the number of annual grasses, biennials dicotyledonous and other weeds in

chickpea crops compared to the control (Table 2).

Five species of spring weeds dominated chickpea crops (93 % of the total number of weeds in the control): cockspur grass (*Echinochloa crus-galli* (L.) Roem. et Schult.), yellow foxtail (*Setaria glauca* (L.) Beauv.), green foxtail (*Setaria viridis* (L.) Beauv.), lamb's quarters (*Chenopodium album* L.), common amaranth (*Amaranthus retroflexus* L.). It was found that the most effective tank mixtures of soil-applied herbicides against of cockspur grass, yellow foxtail, green foxtail, lamb's quarters and common amaranth at the end of the chickpea growing season are following: Tizer + Panda (93 %), Tizer + Kapral (84 %), Tizer + Premium Gold (95 %), Tizer + Panda (89 %) i Tizer +

Stels (98 %).

The fresh weight of annual grasses at the end of the chickpea growing season was most reduced by Tizer + Dual Gold 960 EC herbicide (by 93 %) and biennial dicotyledonous weeds - by Tizer + Panda (by 95 %). According to the total raw weight of annual grasses and biennial dicotyledonous weeds in chickpea crops, this indicator was the most reduced with the tank mixture of Tizer + Panda (by 92 %), which occupied first place, and Tizer + Kapral (by 81 %) and Herb 900 + Kapral (78 %) – and the second and third places, respectively. The lowest total fresh weight of weeds in chickpea crops was when a tank mixture of Tizer + Panda herbicides was applied (Table 3).

### 3. Chickpea yield and fresh weight of weeds depending on the action of tank mixtures of soil-applied herbicides (average for 2016-2018)

Variant	Fresh weight of weeds at the end of the growing season, g/m <sup>2</sup>				Yield, t/ha
	annual grasses	biennial dicotyledonous	perennial dicotyledonous	Total	
Control	271.7	609.0	299.6	1180.3	1.15
Herb 900, 1.25 l/ha + Serp, 0.375 l/ha (standard)	45.5	156.3	309.9	511.7	1.26
Herb 900, 2.0 l/ha + Kapral, 2.0 l/ha	30.5	161.3	264.0	455.8	1.21
Herb 900, 2.0 l/ha + Advokat, 0.3 l/ha	60.6	148.0	319.4	528.0	1.24
Tizer, 2.0 l/ha + Kapral, 2.0 l/ha	42.9	121.6	273.5	438.0	1.19
Tizer, 2.0 l/ha + Advokat, 0.5 l/ha	60.3	178.7	325.6	564.6	1.25
Tizer, 2.0 l/ha + Premium Gold, 3.0 l/ha	69.5	273.6	458.8	801.9	1.30
Tizer, 2.0 l/ha + Panda, 3.5 l/ha	39.8	29.9	360.2	429.9	1.27
Tizer, 2.0 l/ha + Stels, 2.0 l/ha	85.0	212.2	381.7	678.9	1.24
Tizer, 2.0 l/ha + Dual Gold 960 EC, 1.6 l/ha	18.2	243.2	365.6	627.0	1.24
LSD <sub>05</sub>	108.8	385.4	282.6	515.9	0.11

It was found that the level of chickpea yield was most influenced by meteorological conditions and certain groups of weeds. Thus, significant precipitation during May 2016 (the climate normal was almost twice exceeded) and the average daily air temperature reduction to 17.2 °C in the first ten-days of June (climate normal of 19.4 °C) caused significant damage of chickpea plants by ascochyta blight, as a consequence, a low yield in the experiment (0.52 t/ha). Insufficient precipitation in May-June 2017 (52 % less than the climate normal) and significant weed infestation by biennial dicotyledonous species (57 % of the total fresh weight of weeds in control) also led to the formation of low grain yields, which in the average was 0.60 t/ha. The insignificant weed infestation of chickpeas by biennial dicotyledonous species in 2018 (1.6 % of the total number of weeds in

control), despite the arid conditions during May - June (precipitation was 47 % less than the climate normal) resulted to an average yield of 2.59 t/ha.

On average over three years of research, the increase in the chickpea yield due to application tank mixtures of herbicides ranged compared with the control from 0.04 to 0.15 t/ha. As a result of the application of herbicide mixtures such as Tizer + Premium Gold and Tizer + Panda, it was possible to obtain high increases in chickpea yield.

**Conclusions.** Therefore, it was concluded on the base of research results that the tank mixtures of modern soil-applied herbicides do not inhibit the growth and development of chickpea plants. There was a positive effect of herbicides on the formation of fresh weight of nitrogen-fixing nodules on the root system of chickpea

plants, especially the tank mixture of Tizer, 2.0 l/ha + Advokat, 0.5 l/ha herbicides. When applied tank mixture of Tizer, 2.0 l/ha + Panda, 3.5 l/ha, the fresh weight of one chickpea plant was the largest. In addition, this tank mixture was the most effective to reduce the total fresh weight of annual grasses and biennial dicotyledonous weeds in chickpea crops. The

largest increases in grain yield were obtained when applying tank mixtures of Tizer, 2.0 l/ha + Premium Gold, 3.0 l/ha and Tizer + Panda herbicides. In the future, it will be necessary to compare the efficiency of the standard tank mixture of Tizer + Panda with other combinations of soil-applied herbicides at chickpea cultivation.

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