Role of Post-Harvest Residue Treatment on the Spring Crops Productivity in Haplic Chernozems

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Summary

The investigation was carried out at Dobrudzha Agricultural Institute during 2014-2016. The type of the previous crop post-harvest residue treatment (PHR- wheat) on the yields from sprig crops (common bean, maize, sunflower) was investigated in six-field crop rotation. The PHR were utilized in three different ways (removed from the field; chopped and subsequently incorporated into the soil; and burned).

The productivity of the spring crops was significantly affected by the meteorological conditions and by the ways of utilizing the PHR. The complex action of the main meteorological elements was determining for the productivity of common bean and maize. These crops reached maximum productivity in 2014 - 2550 kg/ha and 9417 kg/ha respectively. The sunflower demonstrated high productivity in all three years of the investigation (over 3000 kg/ha), with a maximum in 2016 - 3517 kg/ha.

The removal of the post harvest residues from the field decreased the productivity of common bean and maize in comparison to their plowing or burning. The burning of the PHR had negative effect on the productivity of sunflower in all three years of the investigation. In 2016, the greatest differentiation of yield was observed depending on the way of PHR utilization. Among the three spring crops, the positive effect of the plowing of the PHR was most expressed in sunflower. The interaction between the meteorological factor and the way of post harvest residue utilization was decisive for its productivity. Averaged for the investigated period, the ways of PHR utilization did not significantly influence the productivity of maize.

Key words

ways of PHR utilization, spring crops, yields, grain physical properties

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Introduction

Recycling of crop residues is essential to sustain soil fertility and crop production. Management of crop residues is an integral part of most conservation tillage systems. According to Lal et al., 1999; Lobb et al., 2007 crop residues on the soil surface provide a protective barrier against water and wind erosion and reduce the amount of soil, nutrients, and pesticides that reache streams and rivers. There are as a natural resource and there are generally parts of crops retained in soil after harvesting (Kumar and Goh, 2000; Blanco-Canqui and Lai, 2009). To decrease the application of fertilizers, soil incorporation of crop residues has been suggested as a method of improving soil physical, chemical, and biological properties as well as conserving water and reducing excessive evaporation (Stott et al. 1990; Fischer et al. 2002; Erocli et al., 2008).

Incorporation of crop residues into the soil as a source of nutrients and conservation has been increasing in many parts of the world. Crop residues incorporation releases nutrients into the soil and builds up soil organic matter after decomposition. However, in some situations, crop yield reduces for various reasons such as lack of proper tillage implements and insufficient farmer's knowledge about the crop residues management, retaining heavy residues in wet soil, problems of pests and diseases incidence, weed control, and reduced availability of nutrients for the next crop (Torbert et al., 1999).

Although the effect of straw incorporation on N immobilization in the soil is well known (Christensen, 1986; Toor and Beri, 1991; Bhogal et al., 1997; Mary et al.,1996), a few studies have investigated how time of incorporation and starter-N application influence crop residue decomposition, nutrient release, and crop yields (Adachi et al., 1977; Bijay-Singh et al., 2001). More (or improved) knowledge about residue decomposition dynamics is essential for developing effective management strategies. No single residue management practice is superior under all conditions (Kumar and Goh, 2000).

Schomberg et al. (1994) observed an inverse linear relationship between dry mass remaining and N concentration. These observations imply that the relationship between N and mass loss of residues is likely to be influenced by residue type, soil and environmental conditions, and duration of the study. Years late Burgess et al. (2002) reported and confirmed Schomberg et al. (1994) for net N release by low-N residues, wheat (and maize [*Zea mays* L.]) after 50 to 60% mass loss. When organic materials poor in nitrogen were added, such as hardwood bark and wheat straw, the biological yield was under the control level – 92.1% and 92.8%, respectively (Nankova, 1997). Addition of mineral nitrogen to the applied organic residue caused the highest increase of biological yield in the variants with organic residue poor in nitrogen - 17.2%. Nankova et al. (2010) reported also that the different ways of wheat post harvest residue treatment caused the clearest differentiation in the amounts of the plant available phosphorus in soil. They significantly decreased after removal of post harvest residue (PHR). The nitrogen forms were in higher amounts after bean and sunflower and after incorporating of PHR and showed lower content in the variants with PHR removal and burning. The dynamics in the content of exchangeable potassium was very well expressed, too.

Disposal of crop residues by burning is often criticized for accelerating losses of soil organic matter (SOM) and nutrients, increasing C emissions, causing intense air pollution, and reducing soil microbial activity (Biederbeck et al., 1980; Rasmussen et al., 1980; Kumar and Goh, 2000). Burning of crop residues must be avoided at all costs for environmental reasons.Bijay-Singh, et al. (2004) suggested a lower amount of N immobilization by rice straw containing 6.7 g N kg^{-1} when allowed to decompose for 20 or 30 d before fertilizer N application. Yadvinder-Singh et al (2004) concluded "Farmers will incorporate crop residues only if there are no yield losses or if there is a clear yield advantage over residue burning in the long run. The 7-yr data demonstrate that rice and wheat productivity is not adversely affected when rice residue is incorporated for at least 10 d and preferably 20 d before the establishment of the succeeding crop."

The erosion protection afforded by crop residues on the soil surface diminishes as they decompose and lose both mass and cover. The decay processes in natural ecosystems have been described as a continuum beginning with fresh plant litter and leading to formation of refractory soil organic matter (Melillo et al., 1989).

The purpose of this experiment was to evaluate the effects of wheat post harvest residues in rotation on yield and physical properties of seeds/grain in spring crops.

Materials and methods

The investigation was carried out at Dobrudzha Agricultural Institute during 2014-2016 on Haplic Chernozems. The type of the previous crop post-harvest residue treatment on the yields and grain physical properties were investigated in six-field crop rotation. The crops were arranged in crop rotation as follows: grain maize (hybrid KWS Kladus) – wheat (cultivar Enola) – sunflower (Pioneer P64LE25) – wheat – common bean (cultivar Eleksir) – wheat.

Soil preparation for the spring crops (sunflower, maize and common bean) was done according to the traditional for the region system (TS). This system included plowing at 26-28 cm after harvesting of the previous crop (wheat). Pre-sowing tillage for spring crops involved double cultivation and sowing. Main soil tillage was carried out with tractor Fendt 820 Vario equipped with 5-bodies plough with independently skimmers and non-stop protective devices. Sowing was done with tractor Zetor 9540 6-rawed pneumatic seeder.

The trial was performed on 10 ha area in 4 replicates. The mineral fertilization of the spring crops in the crop rotation were applied as follows: common bean – $N_{60}P_{100}K_0$; sunflower – $N_{60}P_{100}K_0$; and maize – $N_{120}P_{100}K_0$.

Mineral fertilization of wheat was in accordance with the type of the previous crop and its fertilization. Main fertilization of wheat was also done with 100 P_2O_5 kg/ha. Fertilization following previous crop bean was with 90 kg N/ha, and following the other predecessors – with 120 kg N/ha. A part of the nitrogen norm (30 kg N/ha) was introduced prior to main soil tillage, and the remaining amount – prior to beginning of permanent spring vegetation.

The post-harvest residues (PHR) from the crop (*Triticum aestivum* L. variety Enola) were utilized in three different ways: they were removed from the field (1. RF); they were chopped and subsequently incorporated into soil (2. CSIS); or they were burned (3. B).

The statistical analysis of the data was carried out according to the type of the design (ANOVA), running the analysis of variance, and comparison of means using LSD 0.05. After performing the analysis of variance, we compared the means for each treatment using the Waller-Duncan's Multiple Range Test.

Results and discussion

Based on the ANOVA results, both the independent and the combined interaction of factors were highly significant, averaged for the trial and years of investigation (Table 1). Each of the investigated year was influenced to various degrees on the grain/seeds yield. The yields variations in common bean in 2016 and sunflower in 2015 were insignificant. Average for the investigated period the ways of PHR utilization were insignificant only for maize.

The interaction between the meteorology as a factor and the way of PHR utilization was determining for its productivity. The strength of this interaction amounted to 75.47 % (Fig. 1). The productivity of common bean and maize depended mainly on the meteorological conditions over years. The strength of their effect was 62.11 % and 87.27 %, respectively. The independent effect and the ways of PHR utilization had significantly lower influence on the productivity of the crops in the crop rotation. In common bean, the strength of this effect amounted to 18.92 %, while in sunflower it was 13.01 % and in maize - 0.25%.

These data required characterization of the meteorological conditions during the vegetative growth of the spring crops (Fig. 2).

In all three years the mean monthly temperatures during the vegetative growth were above the climatic norm, especially in 2015 and 2016. In 2014 and 2016, the temperature regime was comparatively favorable for the conditions of intensive growth and during flowering, pollination and fertilization, while in 2015 the temperature conditions were extremely unfavorable. They were characterized by high temperatures exceeding 32-35^{0}C during the periods 7th – 9th July, 25th – 30th July and 12th – 15th August.

Table 1. Analysis of variances of productivity according to the ways of PHR utilization over years and averaged for the period 2014 – 2016.

Source	Dependent Variable	df	Mean Square	F	Sig.
	Common bean				
2014	Yields	2	1648.000	7.790	.011
2015	Yields	2	2956.000	61.300	.000
2016	Yields	2	732.000	5.749	.025^{NS}
	Maize				
2014	Yields	2	20565.333	44.006	.000
2015	Yields	2	9105.333	51.670	.000
2016	Yields	2	27601.333	181.588	.000
	Sunflower				
2014	Yields	2	1516.000	18.950	.001
2015	Yields	2	137.333	1.162	.356^{NS}
2016	Yields	2	12857.333	140.092	.000
	For all years				
Years (1)	Common bean	2	8748.000	67.794	.000
	Maize	2	392625.778	1480.572	.000
	Sunflower	2	1889.333	19.545	.000
Treatments of plant residue (2)	Common bean	2	2665.333	20.656	.000
	Maize	2	1112.444	4.195	.026^{NS}
	Sunflower	2	2133.333	22.069	.000
1x2	Common bean	4	1335.333	10.348	.000
	Maize	4	28079.778	105.887	.000
	Sunflower	4	6188.667	64.021	.000

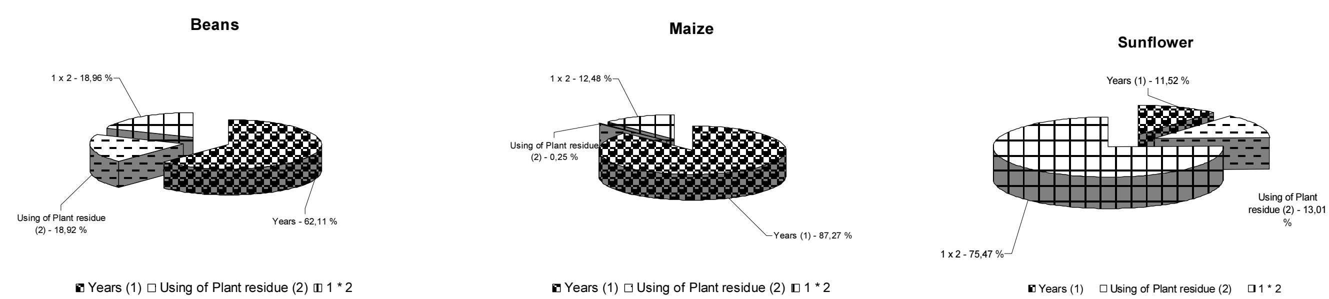

Figure 1. Strength of effect of the factors year and way of PHR utilization on the crop productivity

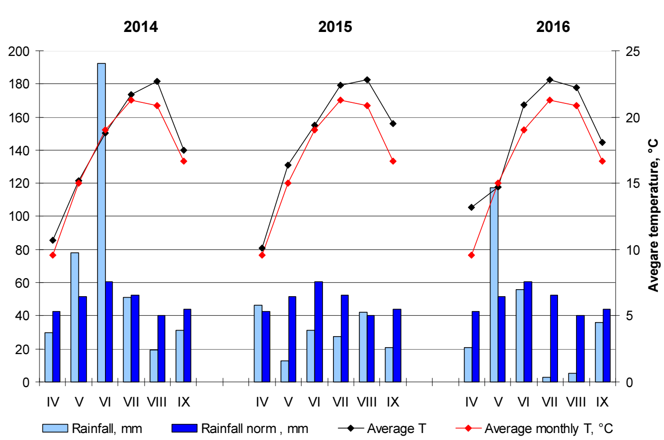

Figure 2. Dynamics of precipitation and temperature values over months during the vegetative growth, and mean long-term norm for 1953-2013

The sum of the autumn and winter precipitation in all three years considerably exceeded the climatic norm; this was a prerequisite for formation of good moisture reserves in soil and for good conditions for preparation of the sowing areas, planting and the initial growth stages of the spring crops. The year 2014 was with the highest amount of vegetation rainfalls, strongly exceeding the mean long-term value with 37.92% for the period April - September. For common bean vegetation, this exceeding was 69.66 %. Regardless of the abundant rainfalls in June, some of which were accompanied by strong winds causing partial lodging in the sunflower and bean crops, the year 2014 can be determined as having very good conditions for the development of the spring crops, in comparison to the other years of the investigation. In 2015 the vegetation rainfalls were 50-60 % from the climatic norm. The high temperatures in July – August, accompanied with severe soil drought, had unfavorable effect on the productivity of the crops. In 2016, long periods of extreme high temperatures exceeding 32^0 C and critical levels

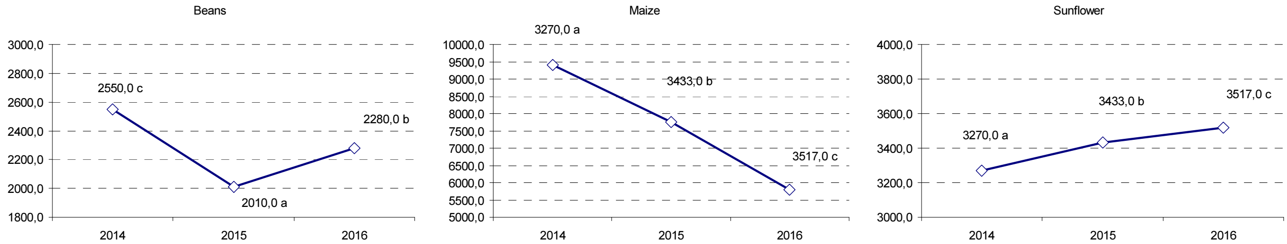

Figure 3. Mean productivity of spring crops over years of investigation

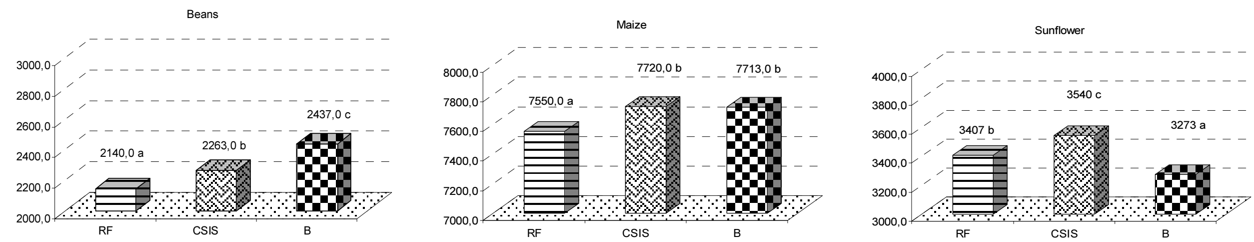

Figure 4. Mean productivity of the spring crops depending on the way of utilization of the previous crop PHR

of relative air humidity did not occur, and the vegetation rainfalls were 94.88 % from the climatic norm. These characteristics of the main meteorological elements explain to a large extent the differentiated reaction of the productivity of each of the spring crops in the crop rotation and the effect of the way of PHR utilization of the predecessor (Fig. 3).

The complex action of the main meteorological elements (rainfalls and temperature) was decisive for the productivity of common bean (cultivar Eliksir) and maize (hybrid KWS Kladus). Under the conditions of the experiment, these crops reached maximum productivity in 2014. The respective mean yields from common bean and maize were 2550 kg/ha and 9417 kg/ha. The severe soil drought during July – August of 2016 had an extremely unfavorable influence on the yield from maize, as compared to the yield from sunflower. Sunflower has a fusiform root which is capable of deeper penetration in comparison to maize. The Express-resistant sunflower (hybrid Pioneer P64LE25) demonstrated high productivity in all three years of the investigation (over 3000 kg/ha), reaching a maximum of 3517 kg/ha in 2016.

The way of management of the previous crop PHR also considerably influenced the crops productivity over the years of investigation. The removal of the PHR from the field decreased the productivity of common bean and maize in comparison to the plowing or burning of PHR (Fig. 4).

The burning of the previous crop PHR had unfavorable effect on the productivity of sunflower in all three years of investigation (Table 2). The highest differentiation in yield depending on the way of PHR utilization was in 2016. The plowing of the plant residues, especially in the presence of large biomass and unfavorable conditions for its decomposition, had a depressing effect on productivity. In our experiment, the common bean, besides having the lowest yield after PHR removal from the field, was also with higher susceptibility after PHR plowing in comparison to maize and sunflower. Common bean (*Phaseolus vulgaris* L.) is grown worldwide in a range of environments, production systems (PS), soil types, and input levels, and suffers from numerous abiotic and biotic constraints (Singh 1992, 2007; Singh et al. 2007; Teran et al. 2009; Urrea et al. 2009).

Table 2. Productivity of the spring crops over years according to the way of PHR utilization (Waller-Duncan N=4)

Variants of Plant residue utilization	Common bean	Maize	Sunflower
	2014		
1. RF	2330 a	8590 a	3420 b
2. CSIS	2590 b	9870 b	3340 b
3. B	2730 b	9790 b	3050 a
	2015		
1. RF	1940 b	7360 a	3500 a
2. CSIS	1780 a	7640 b	3410 a
3. B	2310 c	8290 c	3390 a
	2016		
1. RF	2150 a	6700 c	3300 b
2. CSIS	2420 b	5650 b	4160 c
3. B	2270 ab	5060 a	3090 a

Many researches show that where residues have been incorporated immediately before planting the next crop grain yields are lower than where residues are removed or burned. The main reason is in N immobilization, a problem that is attributable to the slow rates of residue decay (Sidhu and Beri, 1989; Beri et al., 1995). Other potential problems of residue incorporation include accumulation of phenolic acids in soil and increased CH_4 emissions under flooded conditions (Grace et al., 2003). In this case, the timing of incorporation of crop residues is more important than the amount. The potential benefits of shallow incorporation shortly after crop harvest include accelerated aerobic decomposition of crop residues (about 50% of the C within 30–40 d), leading to increased N availability (Witt et al., 2000), and reduced CH_4 emissions (Wassmann et al., 2000). Early incorporation also allows additional time for phenol degradation to occur under aerobic conditions, thereby avoiding any adverse effect on germinating seeds and seedlings.

Table 3. Analysis of the variances of 1000 kernel weight

Source	df	Mean Square	F	Sig.
Common bean				
Years (1)	2	924.384	3.859	.034^{NS}
Treatments of Plant Residue (2)	2	109.134	.456	.639^{NS}
1x 2	4	398.516	1.664	.187^{NS}
Maize				
Years (1)	2	5353.697	61.273	.000
Treatments of Plant Residue (2)	2	14.343	.164	.849^{NS}
1x 2	4	138.911	1.590	.206^{NS}
Sunflower				
Years (1)	2	999.879	233.456	.000
Treatments of Plant Residue (2)	2	62.713	14.642	.000
1 x 2	4	167.591	39.130	.000

to 441.41 g (2014), and this variation was in the variant with burning of the plant residues (Table 4). Although the differences in the 1000 kernel weight in this crop were not significant, the seeds were larger in 2014.

The differentiation in the values of the 1000 kernel weight in maize over years was very well expressed. This variation was from 251.89 g (2016) to 301.93 g (2014), respectively in variants 3 (B) and 2 (CSIS). Again, the highest values of the index were determined in 2014.

The 1000 kernel weight of the sunflower seeds also varied to a maximum degree - 48.60 g (2016) to 76.71 g (2015). This variation was also determined in the variant with PHR removal.

Averaged for the period, the insignificant differences depending on the ways of the PHR treatment in common bean and maize and their strong effect on 1000 kernel weigh of sunflower were clearly

Table 4. 1000 kernel weight by year and crop depending on the way of PRH treatment of the predecessor

Variants of treatment	Common bean			Maize			Sunflower		
of plant residue	2014	2015	2016	2014	2015	2016	2014	2015	2016
1. RF	417.85	418.28	422.08	287.24	287.11	257.51	66.73	76.71	48.60
2. CSIS	434.07	428.50	410.48	301.93	281.55	253.76	55.36	73.27	60.85
3. B	441.41	424.80	408.38	297.00	282.41	251.89	63.89	75.34	63.20
Average	431.11^{b}	423.86^{ab}	413.64^{a}	295.39^{c}	283.69^{b}	254.39^{a}	61.99^{b}	75.11^{c}	57.55^{a}

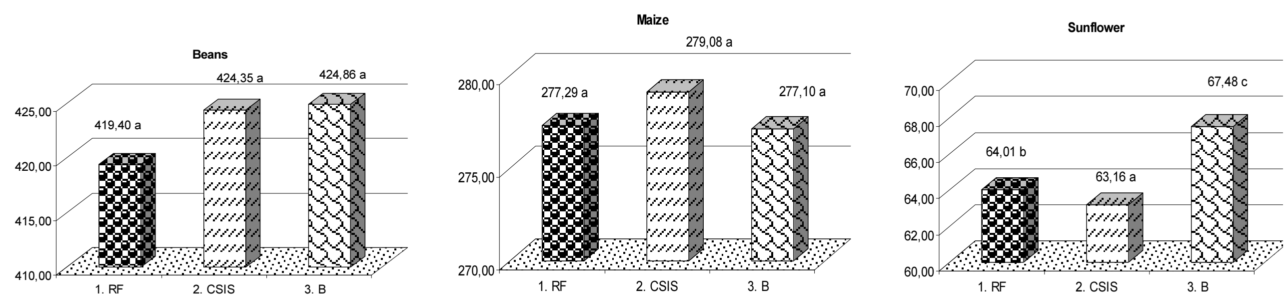

Figure 5. Mean 1000 kernel weight of the spring crops depending on the way of utilization of the previous crop PHR, g

Among the three spring crops, the positive effect of the plowing of PHR was best expressed in sunflower. Averaged for the period, the independent effect from the ways of PHR utilization did not have a significant effect on the productivity of maize.

The complex interaction of the tested factors had a maximum-level significant effect on the productivity of the spring crops in the crop rotation.

The analysis of the variances of 1000 kernel weight showed that during the investigated period the values of common bean were not significantly influenced by the meteorological conditions of the year and the ways of PHR treatment, or by their interaction (Table 3). A similar tendency was observed in maize, too, but in this case the independent effect of the year was significant. The variations in the seed size of the Express-resistant sunflower hybrid Pioneer P64LE25 were influenced significantly by the direct and combined interaction of the factors in the experiment. The values of 1000 kernel weigh in common bean varied from 408.38 g (2016)

demonstrated (Fig. 5). The established correlations between yield and 1000 kernel weigh of common bean and sunflower were positive but statistically not significant. In maize, the values of the correlation were high (0.860**).

Conclusions

The productivity of the spring crops in the crop rotation was significantly influenced by the meteorological conditions during the investigated period and the ways of utilizing the plant residues from the previous crop. The complex action of the main meteorological elements (rainfalls and temperature) was decisive for the productivity of common bean (cultivar Eleksir) and maize (hybrid KWS Kladus). Under the conditions of the experiment, these crops reached maximum productivity in 2014. The mean yields were 2550 kg/ha and 9417 kg/ha, respectively for common bean and maize. The Express-resistant sunflower (hybrid Pioneer P64LE25) gave high yields in all three years of the investigation (over 3000 kg/ha), with a maximum in 2016 - 3517 kg/ha.

The removal of the plant residues from the field reduced common bean and maize productivity, as compared to their plowing or burning. Sunflower reacted positively to plowing of the residues and decreased its yield after their burning during the three years of the investigation. The differentiation in the yields of the spring crops depending on the ways of PHR utilization was best expressed under the conditions of year 2016. A determining role for the productivity of this crop was played by the interaction of the meteorological factor with the way of PHR treatment. The strength of this interaction amounted to 75.47 %. The productivity of common bean and maize depended primarily on the meteorological conditions of the years. The strength of their effect was 62.11% and 87.27%, respectively. The independent effect of the way of using the plant residues influenced considerably less the productivity of the crops in the crop rotation, and in maize it was statistically not significant.

Averaged for the period of investigation, the ways of PHR utilization and their interaction with the meteorological conditions of the year had insignificant effect on 1000 seed weight of common bean and maize. In sunflower, however, this effect was strongly expressed.

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