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The Efficiency of Mineral and Water-Soluble Complex Fertilizers in Potato Fields

G.H. Gasparyan, L.S. Yeritsyan, S.A. Ayvazyan, A.J. Sahakyan
"H. Petrosyan Scientific Center of Soil Science, Melioration and Agrochemistry", ANAU
gayanehgasparyan@gmail.com, lusineyeritsyan1969@gmail.com, ayvazyan.sus@mail.ru, sahakyan48@mail.ru

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ABSTRACT

Application of fertilizers is among the prior agriculture measures to achieve sustainable potato yield in conditions of leached soils of Lori region, poor in essential plant nutrients. The field experiments established that to obtain maximum potato yield in addition to the introduction of the main mineral fertilizer (*NPK*) it is necessary to apply complex water-soluble fertilizer (CWF) via foliar feeding thrice during the vegetation period with 10-12 days of interval. In this case the yield amount was 286 c/ha, 40.0 % of which was large and 35.0 % were medium size. The tuber's chemical composition was also improved. In the case of using $N_{120}P_{120}K_{120}$ the yield amount was 261.0 c/ha, out of which 30.2 % were large and 40.5 % were medium size, while in the control variant 207.5 c/ha yield was received, out of which only 15.1 % were large and 35.9 % – medium in size.

Introduction

Potato is a leading crop in the Lori region, where both large and small-scale farms are engaged in potato cultivation. Anyhow, according to statistical data, its average yield capacity and profitability are still low. According to the observations and studies conducted in different communities of the mentioned region, one of the main reasons for low potato yield capacity is the use of an unjustified amount of fertilizers in conditions of soils with poor fertility, which results in the destruction of plant nutrition, slow-down of its growth, reduction of yield capacity and deterioration of its quality (Atlas of soils of RA, 1990; Yurevna, 2020; Yakushev, et al., 2008). Another reason for low yield production is the damage caused by diseases and pests which are not controlled efficiently. Therefore the vegetation period of plant terminates much earlier (Avagyan, et al., 2017; Yeritsyan, et al., 2017).

It is known that potato's nutrient demand is rather high. For example, to produce a 300-350 c/ha yield the plant takes up 180-210 kg nitrogen (*N*), 60-70 kg phosphorus (P_2O_5) and 270-315 kg potassium (K_2O) from the soil. Whereas, in the carbonate and leached black soils of the RA, including in those of the Lori region, such amounts of available nutrients are missing, which is confirmed upon the results of agrochemical analyses and field experiments (Atlas of soils of RA, 1990; Edilyan, 1976). So, in the soils of Lori region there is a lack of plant-available potassium, then phosphorus and nitrogen.

The soils of the mentioned region are also very poor in micronutrients, which have a multifunctional role in the improvement of plants nutrition process. They promote the yield increase, yield quality and tubers' retention capacity by improving the nutrition with nitrogen, phosphorus and potassium (Atlas of soils of RA, 1990; Chernavina, 1970).

To regulate the nutrition process of the plants, including potatoes, in fast manners, such fertilizers are used in recent years, which are rapidly imbibed in case of spraying them on the leaves and thus, exert a quick effect on the plant nutrition process, growth, yield capacity and tuber's quality. Considering the paramount importance/urgency of applying such fertilizers, currently numerous fertilizers with the mentioned characteristics (*N:P:K=20:20:20*; *N:P:K=0:52:34*) are being imported into the republic (Gasparyan, et al., 2020; Sahakyan, et al., 2020).

Taking into account all aforestated circumstances, an objective was set up to develop an efficient fertilization system for the increase of potato yield capacity, which would also partially mitigate the development of diseases and pests.To solve the mentioned problems, our research group has studied the effect of different combinations of mineral and water-soluble complex fertilizers on the growth, yield capacity and tuber's chemical composition of the potato variety "Marfona" in the leached black soils of the Lori region.

Materials and methods

The field experiments have been conducted in the Aygehat community of the Lori region in 4 replications per the following experimental patterns:

1. Without fertilization (control)
2. N_{120}
3. $N_{120}P_{120}$
4. $N_{120}P_{120}K_{120}$
5. $N_{120}P_{120}K_{120}+CWF$ by soaking the tubers, then conducting foliar feeding during the vegetation period thrice with 10-15-day intervals.

The laboratory studies were conducted at the ANAU branch of H. Petrosyan Scientific Center of Soil Science, Agrochemistry and Melioration, in 2020-2021. The size of the experimental bed was 98 m^2 (4.9 m x 20 m), the feeding area per plant was 0.21 m^2 (0.7m x 0.3 m), and the potato variety was Marfona (www.potato.professor home.ru). It is a mid-early-ripening variety with 80-90 vegetation period; anyhow, in conditions of relatively temperate climate conditions of the Lori region the tubers maturation and the natural dying of vines are somehow delayed. The studied variety has a more than average yielding capacity, the marketable yield of the tubers amounts to 90-95 %. The resistance towards foliar blight, leaf curl and tuber scab is rather high (www.kartofan.org). In the experiments the mineral fertilizers – double superphosphate and potassium chloride – were applied during the pre-treatment of the soil, while the ammonium saltpeter (30 %) was applied via sowing and the remaining amount was used during the weeding-hilling period. The water-soluble complex fertilizer was used before planting via tubers spraying and then it was applied when the plant height increased up to 10-15 cm. The process was repeated twice more with 10-15-day interval. The potato tops had been reaped 12 days before harvesting process. During the vegetation period phenological observations, measurements and calculations were carried out. The yield accounting has been conducted after harvesting the entire yield from the experimental bed via weighing method. The tubers have been grouped into large, average, and small sizes. The experimental error has been estimated (Ex%) and the least significant difference ($LSD_{0.95}$) between the variants according to Dospekhov's method (Dospekhov, 1965). The soil, plant and tubers analyses have been conducted per the methods accepted in the RA (Viktorov, 1969; Yagodin, 1987).

Results and discussions

The experiments of field fertilization were conducted in the mid-power leached black soils, which are characterized by the following chemical properties: the mechanical components are clay and sandy, heavy; when drying out they get partially compacted and encrusted, the humus content in the arable layer (0-30 cm) makes 4.41 %, and in the sub-surface layer it is only 1.25 %. They are free from carbonates, the soil reaction (*pH*) is weakly alkaline and makes 7.8. In the soil water extract the ratio of *Ca-Mg* makes 60:40 %. The content of mobile nitrogen in the soil arable layer makes 4.35 mg per the Turin-Kononova method, as to the Machigin's method the phosphorus content makes 1.08 mg and the potassium content in the extract of Machigin's solution makes 14.58 mg in 100 g soil. According to the data on the limited numbers of the nutrient provision of soil accepted in the RA, the mentioned soils are considered to be poorly provided with essential nutrients (*NPK*).

It should be added that the lack of nitrogen and phosphorus is peculiar to the soils of the RA, while the shortage of mobile potassium is recorded in numerous land areas of the Lori province. Thus, the application of potash fertilizers in this zone is ultimately important (Atlas of soils of the RA, 1990; Edilyan, 1976). The observations, measurements and calculations conducted throughout the plant vegetation period have testified that the application of fertilizers has exerted a noticeably positive effects on the transitional phases in the plant development period, their growing process, as well as on the tubers' yield capacity and qualitative indices.

So, let's consider the impact of fertilizers on the transitional phases of the plant development process: the mineral fertilizers showed zero effect on the tuber's sprouting time, whereas by the use of CWF the sprouting process went ahead by one day. Therefore, it can be concluded that during the sprouting period the applied CWF affected the biological processes taking place in the tuber (Ivanyushkin, et al., 2018; Khoroshkin, 2015).

A similar effect was also recorded in the fields of cereal crops, e.g., winter wheat and spring barley. Moreover, the Complex Water-Soluble Fertilizer has demonstrated favorable effect on the vigorousness and sprouting capacity of the seeds in these and other crops (Gasparyan, et al., 2020; Abitov, 2014; Yeritsyan, et al., 2017). So, the following picture is depicted when studying the effect of fertilizers on the times of plant budding, blossoming and natural dying of potato tops. In the control variant the budding, as well as the blossoming period was sped up. The natural dying period of the potato tops was also accelerated. This indicates that the life span of the plants was reduced, which also results in the reduction of plants yield capacity and in the decline of marketable tuber yield. Whereas in the variants where fertilizers were applied, particularly in the case of applying CWF on the background of mineral fertilizers, the budding and further phases were delayed, which is more obvious in the case of applying water-soluble fertilizers on the background of mineral fertilizers. This testifies that the transitional phases in the plants development period, particularly the period of natural death were prolonged upon the use of CWF. That is, the complex water-soluble fertilizers have promoted the sustenance of plants bio-activity, as a result of which the yield is still increasing. Regarding the mentioned facts, it is known that the crops with long vegetation, for instance, late-ripening potatoes, are endowed with higher yielding capacity (Butov, et al., 2013; Vlasenko, 1987; Zamotaeva, 1987). Considering that the potato yield capacity is also related to the intensity of the aboveground mass growth and that a correlative relationship is established between the plant growth and yield capacity within a certain limit, the effect of fertilizers on the plant growing peculiarities has been determined (Table 2).

Table 1. The effect of mineral and water-soluble complex fertilizers on the times of potato developmental stages (average for 2020-2021)*

N	Variants	Times of developmental stages, day			
		sprouting	budding	blossoming	from sprouting to the natural dying of tops
1	Without fertilization (control)	18	39	61	91
2	N_{120}	18	45	68	99
3	$N_{120}P_{120}$	18	45	65	98
4	$N_{120}P_{120}K_{120}$	18	45	62	98
5	$N_{120}P_{120}K_{120}$ +CWF	17	47	70	114

Table 2. The effect of mineral and water-soluble complex fertilizer on the growing peculiarities of potato plant (average for 2020-2021)*

N	Variants	Plants height, cm	Number of stems, n	Branching degree, n	The weight of aboveground mass after blossoming, g
1	Without fertilization (control)	34	4.3	3.5	341
2	N_{120}	40	4.7	4.0	392
3	$N_{120}P_{120}$	42	5.1	4.4	409
4	$N_{120}P_{120}K_{120}$	42	5.6	4.6	429
5	$N_{120}P_{120}K_{120}$ +CWF	45	5.6	5.1	474

Table 3. The effect of mineral and water-soluble complex fertilizer on the potato yield structure (average for 2020-2021)*

N	Variants	The weight of the tubers mass per a bush, g			
		total	including		
			large	average	small
1	Without fertilization (control)	442.9	66.8	159.1	217.0
2	N_{120}	502.1	125.5	180.7	195.9
3	$N_{120}P_{120}$	524.4	146.8	204.0	173.6
4	$N_{120}P_{120}K_{120}$	553.5	167.2	224.2	162.1
5	$N_{120}P_{120}K_{120}$ +CWF	604.9	242.0	211.5	151.4

*Composed by the authors.

According to the data in table 2, the indices of plant height, stem number per a bush, branching degree and the weight of aboveground mass are lower in the unfertilized variant. Thus, the plants height makes 34 cm, the number of stems per a bush amounts to 4.3 and after blossoming the weight of a bush aboveground mass makes 341 g. In the fertilized variants, the mentioned indicators are much higher but the highest result was recorded in the variant where CWF on the background of mineral fertilizers was applied. In the latter variant the plant height was 45 cm, the number of stems per a bush was 5.6 and the weight of a bush aboveground mass amounted to 474 g. Whereas, in the variant where only nitrogen was applied (N_{120}) the plant height made 40 cm, the number of stems was 4.7 n and the weight of a bush aboveground mass amounted to 392 g. The mentioned data are much higher than those of the control variant but they considerably yield to those where $N_{120}P_{120}$ or $N_{120}P_{120}K_{120}$ have been used, while are well behind the variant where $N_{120}P_{120}K_{120}$ +*CWF* has been applied.

It is evident that when studying the efficiency of any agro-technical measure in the potato sowings, it is essential to reveal the effect of the implemented measures on the yield structure, which accounts for the share of commercial products (Table 3).

According to the data in the Table 3 the weight of tubers per bush and the share of different fractions therein depend on the fertilization variant. So, in the control variant the total tubers mass per bush makes 442.9 g, from which the share of the large tubers makes only 66.8 g (15.1 %), while the share of the small and medium tubers makes 217.0 g (49.0 %) and 159.1 g (35.9 %) respectively. Whereas, in the variants where fertilizers have been used, the share of large and then small-sized tubers sharply increases amounting to 25.0-40.0 % and 36.0-40.5 %, respectively, besides, higher yield (large and mid-sized) was received in the variants where also CWF was applied in the $N_{120}P_{120}K_{120}$ fertilization system. In this variant the tubers mass per a bush exceeds that of the control variant by 36.6 %, while against the variant of $N_{120}P_{120}K_{120}$ the surplus makes 9.3 %, while the mass of large tubers makes 242.0 g (40.0 %) and that of the medium-sized tubers makes 211.5 g (35.0 %). In addition, the tubers' marketable appearance in the $N_{120}P_{120}K_{120}$+*CWF* variant has improved and the damage caused by the disease (potato scab) has been reduced.

It is clear that by contributing to the growth of aboveground mass of the plant, the increase of leaves chlorophyll content, as well as to the considerable prolongation of the plants bioactivity and the period of natural dying of the potato tops/haulms, the fertilizers promoted the increase of the tubers yield capacity, the intensity of which is again related to the fertilization system (Table 4).

Thus, per the two-year average data, the tuber yield in the control variant makes 207.5 c/ha, while in the fertilized variants it amounts to 235.5-286.0 c/ha, which exceeds the same index of the control variant by 28.0-78.5 c/ha (13.5-37.8 %). According to the data of Table 4, there is a significant difference between the fertilized variants as well. The yield index is considerably lower in the variant where only nitrogen (N_{120}) with the dosage of 235.5 c/ha has been used. In the case of applying phosphorus along with nitrogen, the yield capacity increased up to 246.5 c/ha, while per the use of $N_{120}P_{120}K_{120}$ it amounted to 261.0 c/ha. It should be noted that the efficiency of phosphoric and potash fertilizer is related to the low content of phosphorus and potassium in the experimental plot, which is characteristic of the land areas of the Lori region.

Table 4. The effect of mineral and water-soluble complex fertilizers on the yield capacity and qualitative composition of the potato tuber*

Variants	2020	2021			The content in the tubers					
	yield, c/ha	yield, c/ha	Average yield, c/ha	Surplus, c/ha	dry matters, %	starch, %	NO_3 mg in 1 kg fresh mass, mg	Nitrogen (*N*), %	Phosphorus (P_2O_5), %	Potassium (K_2O), %
1	225	190	207.5	-	18.6	13.2	39.6	0.18	0.16	0.31
2	258	213	235.5	28.0	17.8	13.0	64.2	0.45	0.11	0.25
3	270	223	246.5	39.0	18.7	14.0	48.5	0.38	0.23	0.24
4	283	239	261.0	53.5	19.0	14.3	31.6	0.27	0.25	0.51
5	312	260	286.0	78.5	19.5	15.1	20.3	0.25	0.32	0.63

Note. *Variants: 1. Without fertilization (control), 2. N_{120}, 3. $N_{120}P_{120}$, 4. $N_{120}P_{120}K_{120}$ 5. $N_{120}P_{120}K_{120}$+CWF*

*Composed by the authors.

The higher yield was recorded in the variant where on the background of $N_{120}P_{120}K_{120}$ CWF was applied by soaking the seeds with the solution of the mentioned fertilizer and then implementing foliar feeding twice during the vegetation period. In the mentioned variant the average tuber yield has amounted to 286.0 c/ha, which exceeds the analogous index of the control variant by 78.5 c/ha (37.8 %), and that of the background variant – by 25.0 c/ha (9. 6 %).

Conclusion

The amount of humus substances in the leached and regular carbonate black soils of the Lori region is lower than those peculiar to the soils of the same type. The mentioned soils are also poor in the plant-available basic nutrients, such as nitrogen, phosphorus and potassium. They are also endowed with unfavorable agro-physical properties. In such soil conditions the potato plant provides only 190-225 c/ha yield. In order to improve the fertility of the mentioned soils and to increase potato yield capacity, it is important to apply an efficient fertilization system.

Among the studied fertilization systems (N_{120}; $N_{120}P_{120}$; $N_{120}P_{120}K_{120}$ and $N_{120}P_{120}K_{120}$+CWF); $N_{120}P_{120}K_{120}$+CWF system is the most efficient one, which has considerably improved the plant growth and yield capacity against the variant of $N_{120}P_{12}K_{120}$. The yield surplus against the control variant has made 78.5 c/ha (37.8 %), while against the variant of $N_{120}P_{120}K_{120}$ it amounts to 25.0 c/ha (9.6 %).

In all fertilization variants the natural dying times of the haulms were prolonged by 8-23 days; the longest period was recorded in the variant of $N_{120}P_{120}K_{120}$+CWF, which lasted 23 days. Besides, when applying the mentioned fertilization system, the tuber qualitative properties were improved, the content of dry matters in the tuber increased by 0.9 %, that of starch – by 1.9 %, and phosphorus and potassium contents – by 0.16 % and 0.32 %, respectively, as compared to those of the control variant.

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