Res. on Crops **22** (Spl. Issue) : 75-78 (2021) DOI : 10.31830/2348-7542.2021.018
With two figures
Printed in India

The influence of phytohormone ethylene on growth, development and yield of potato

S. V. MALTSEV*, V. N. ZEIRUK, G. L. BELOV, S. V. VASIL'EVA AND M. K. DEREVJAGINA

Russian Potato Research Centre
23 Letter B Lorch Street, Suburban (Dacha) Settlement Kraskovo
Lyuberetsky District, Moskow Oblast, 140051, Russia
**(e-mail : stanmalcev@yandex.ru)*

(Received : December 12, 2020/Accepted : January 27, 2021)

ABSTRACT

Ethylene is one of the first discovered gaseous plant hormones possessing a very wide spectrum of biological effect. It is used for quite a while in agriculture, mainly for ripening of fruits and berries. However, in the sphere of potato growing in general and in the storage of seed potatoes in particular, its effectiveness has not been fully studied yet. The aim of this research was to determine the ethylene effect on growth, development and yield of potatoes. Gas treatment in potato storage was carried out during 2015 to 2017 using the Restrain technology. The tubers were planted in two districts (Lyuberetsky and Ozyorsky) of Moscow region with similar soil and climatic conditions including application of irrigation. In this study, it was found that treatment of seed potato tubers with ethylene at a storage temperature of 4°C promoted: (i) change in biochemical indicators of tubers (dry matter content and sucrose), which indicates the release of tubers from the state of dormancy period, accompanied by an increase in the intensity of breathing, (ii) increase in the number of opened eyes (mainly due to the side eyes due to excluding apical dominance), (iii) earlier (3-5 days) and even emergence of sprouts, which, as a consequence, prolonged the vegetation period until the time of the wilting, which occurred approximately in the same time as the variants without treatment, (iv) development of bigger amount of stems on the plant (by 19.9-36.0%) and (v) increase in the number of tubers per plant (by 6.3-19.0%, especially on Gala variety) with an earlier start of tuberization. It was observed that due to treatment of seed potato tubers with ethylene, the total potato yield depending on the variety, area of cultivation and irrigation application increased by 9.9 to 19.0% (1.2 to 6.4 t/ha by weight). The commodity yield increased by 7.0 to 23.9% (1.0 to 6.6 t/ha by weight). It was also observed that the potato crop structure was more even with the treatment of seed potato with ethylene.

Key Words : Ethylene, phytohormone, potato, sprout, stem, tuber, variety, yield

INTRODUCTION

The peculiarity of ethylene as a phytohormone is that it can act both as a stimulant and as an inhibitor of potato germination. Short-term (72 hrs) exposure to ethylene (in the range of 0.02 to 20 ppm) promotes the exit of tubers from the state of natural rest and stimulates the beginning of their germination, and continuous exposure during long-term storage of potatoes, on the contrary, suppresses the growth of sprouts. There is evidence (Pal *et al.*, 2007; Hosseininejadian and Naderidarbaghshahi, 2018; Ravich, 2018; Maltsev *et al.*, 2019) that ethylene increases the number of sprouts, but at the same time prevents their growth in length (elongation). Perception of ethylene begins with its binding to receptors (present in all higher plants), which are localized in membrane of the endoplasmic reticulum and golgi apparatus. The unusual intracellular localization of receptors does not interfere with perception of hormone, since ethylene gas diffuses freely in an aqueous and lipid environment. It is assumed that the binding of ethylene to receptor histidine kinases changes their conformation, inactivates

receptor complexes with CTR1 (Cep/Tpe protein kinase, similar to Raf-family protein kinases). This leads to dephosphorylation of the protein EIN2 (a protein similar to the Nramp metal-ion transporter), cleavage of its C-terminal domain, which is transferred to the nucleus and initiates the transcription response of ethylene-dependent genes by sequentially activating the transcription factors of the families EIN3/EIL1 and ERF (Cho and Yoo, 2015).

MATERIALS AND METHODS

Experiments with treatment of seed potatoes with ethylene were conducted on the base of JSC "Ozery" storage facilities in the Ozyorsky district of Moscow region. Storage capacity 2000 tones gasification was carried out using the technology of the company "Restrain", adapted to the Russia's conditions. The equipment and the principles of it's work are shown in Fig. 1.

Adaptation of the technology was that the storage temperature of seed potatoes was not 6 to 8^{0}C, as recommended for climatic conditions in Western countries, but 4^{0}C and the period of ethylene gassing was 1 month longer (from November to the end of April, not to the end of March). Such an approach was chosen because winters in the Central region of Russia are colder and longer, potato planting begins 1 month later and, therefore, it is risky to maintain a high temperature in storage, since in this case untimely germination of tubers is not excluded (at least some varieties), which is unacceptable. In order to start the sprouting of tubers in time, the ethylene supply was stopped for 3 to 5 days before planting. Potatoes treated with ethylene were planted in two field experiments carried out in Moscow region during 2015 to 2017.

Field Experiment I

The first field experiment was two-factorial and was conducted in Lyuberetsky district at the experimental base "Korenevo". The area of each experimental plot on the sod-podzolic sandy loam was 25 m^2 and the number of plots were 18):

Factor A - Treatments of seed tubers with ethylene:

1) Control (without treatment).
2) Gassing at a dose of 30 units according to the classification of the company "Restrain" starting from November to the end of April.

Factor B - Varieties of potato:

1) Lady Claire (early ripening period)
2) Gala (mid-early)
3) Saturna (mid-late).

These varieties of foreign selection are widely known and widespread in Russia and abroad, especially in ware and "chips" potatoes production.

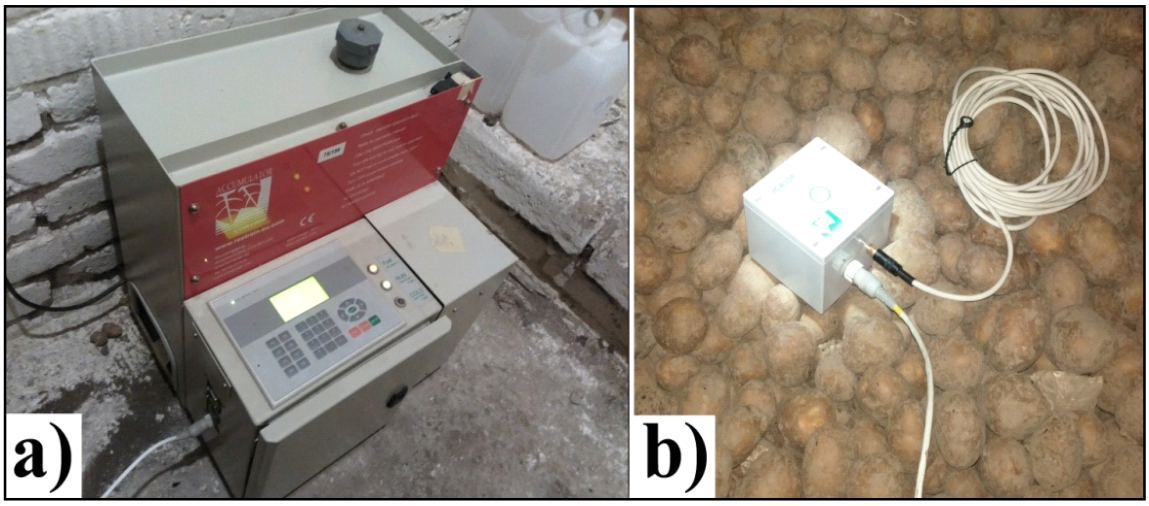

Fig. 1. Equipment of "Restrain" company used in experiment: a) an ethylene generator (installed in the storage and performs a catalytic decomposition of 96% ethanol on ethylene and water when heated), b) an ethylene concentration sensor placed on the surface of potatoes pile for control of generator operation.

Field Experiment II

The second field experiment was three-factorial and was carried out in Ozyorsky district with large-scale potato production (10 hectares for each experimental plot) at the experimental base - JSC "Ozery" farm. Soil type was sod-podzolic loam.

Factors A and B

The treatments of factor A (ethylene) and factor B (varieties) were the same as in case of the first field experiment.

Factor C - Application of irrigation:

1) Control (without irrigation)
2) Watering 2-3 times by 200 m^3/ha using sprinklers of the "Frigate" type.

With the exception of irrigation, the technology of potato growing in both districts of the Moscow region was the same. The planting time was first decade of May. Planting density was 45000 tubers/ha. Row spacing was kept as 75 cm. The mineral fertilizer dose was $N_{60}P_{120}K_{120}$ (local application at planting time).

Assessment of biochemical and biometric indicators, and potato yield was carried out according to the methods of Russian Potato Research Centre and State Standard 29270-95 with mathematical data processing by method of dispersion analysis (Dospekhov, 1985).

RESULTS AND DISCUSSION

In the course of 3 years research, July and August 2015 appeared to be drought, especially in the Lyuberetsky district of Moscow region. In 2016 and 2017 growing seasons, weather conditions were more favourable and close to the average long-term data.

Because of such specific weather conditions in 2015, potato varieties that have a longer maturation period (Gala and especially variety Saturna) when grown in Lyuberetsky region without irrigation, did not have time to realize their full biological potential. The early maturing variety 'Lady Clare', on the contrary, managed to accumulate a fairly high yield before the onset of drought.

As a result of this study, it was found that the treatment of potato seed tubers with ethylene in 2015 contributed to an increase in number of opened eyes (mainly due to lateral ones with the exception of apical dominance, earlier emergence of seedlings (by 3 to 5 days compared to the control), plants were higher in length by 3 to 5 cm and ahead of the control variant in the size of the leaf surface on the same date. The number of stems per bush was higher by 22.4, 40.0 and 22.2% for varieties Lady Claire, Gala and Saturna, respectively. The tuberization phase started few days earlier in all the varieties. The number of tubers per plant was higher by 22.2, 31.9 and 19.1% for the varieties Lady Claire, Gala and Saturna, respectively.

As a result, due to the above mentioned factors, the yield of potato with various ethylene treatments of seed tubers in 2015 for varieties Lady Claire, Gala and Saturna increased depending on growing location and irrigation application from 14. 5 to 42.9, 21.9 to 29.9 and 4.9 to 16.3% or from 4.5 to 7.2, 3.5 to 7.5 and 0.7 to 4.2 t/ha by weight, respectively. A more uniform crop structure was also recorded with the seed potato treatment with ethylene.

Established patterns apply to all three varieties studied, but they were particularly evident in 2015 on an early variety Lady Claire when grown in Lyuberetsky region without irrigation. Under these conditions, the increase in total yield (and to an even greater extent in ware potato yield, which reached a value of 62.3% or 7.6 t/ha by weight) was mainly due to the shift in passage of phenological phases of plant development to earlier periods, which under these weather conditions was critical for the accumulation of yield in general and yield of ware potatoes in particular. Varieties of later groups of ripeness (especially Saturna) in such conditions with a shortened favorable growing season due to the onset of drought in August were less responsive to the treatment of seed tubers with ethylene, and although their yield also increased, but the share of small fraction in crop structure was higher.

Due to more favorable weather conditions, irrigation efficiency in 2016-2017 was not as high as in 2015. The increase in yield ranged from 3 to 16% for varieties, or from 0.8 to 4.0 t/ha by weight. The yield of potatoes grown in Ozyorsky District on loamy soil was higher in 2016-2017 than when grown in Lyuberetsky one on sandy loam soil by 7-16% or by 1.5-4.4 t/ha by weight (depending on the variety), which is slightly less than the difference noted in 2015. The use of ethylene

on seed potatoes in 2016 and 2017, due to their similarity in meteorological conditions, had a very similar effect on the growth of biometric indicators and yields (Fig. 2). In relative values (as a percentage from control), the effect of ethylene was noticeably lower than in 2015 (for the varieties Lady Clare, Gala and Saturna, the yield increase was respectively 6,9-9,5%; 11,1-17,8%; 5,6-15,3%), however, there was almost no difference in absolute values (in t/ha by weight) compared to 2015 (for the varieties 1,8-2,8; 3,1-6,2; 1,2-4,5 t / ha, respectively).

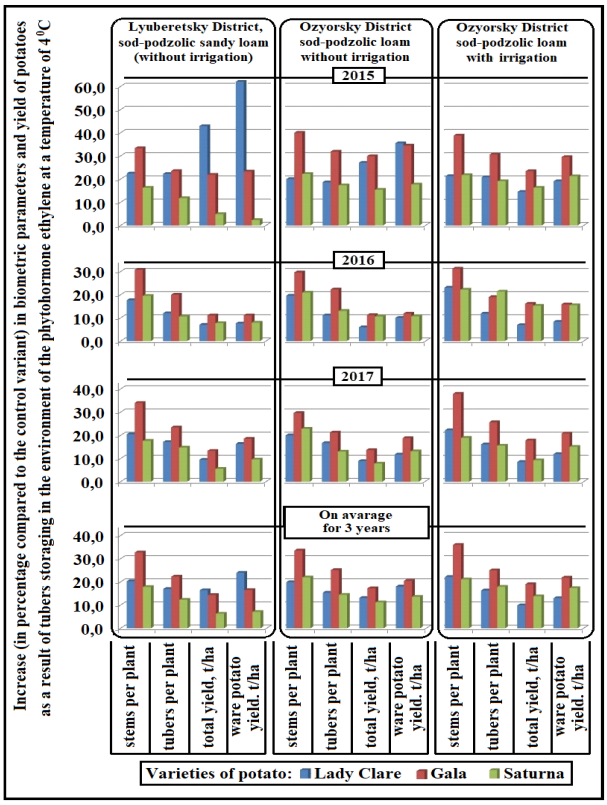

Fig. 2. Influence of seed tubers treatment with ethylene on potato growth, development and yield indicators depending on the studied factors.

On average, for 3 years, out of the three studied varieties, when measured in absolute values, the most responsive to the treatment of seed tubers with ethylene in terms of the increase in number of stems and tubers per bush, the increase in total and commodity productivity (in t/ha) was the Gala variety when grown on sod-podzolic loam soil in Ozyorsky District of Moscow region using irrigation. The increase in above mentioned indicators was 2.3 stems/bush; 4.8 tubers/bush; 6.4 t/ha and 6.6 t/ha.

It is important to note that the increase in potato yield (based on the additional number of stems per bush) was not accompanied by a decrease of dry matter and starch content in tubers, what often happens in case of a "race for a high yield" because of application of additional doses of mineral fertilizers. Together with achieving a more uniform crop structure, this allows to grow high-quality raw materials for various types of potato processing.

CONCLUSIONS

Treatment of seed potato tubers with ethylene at a storage temperature of 4 ^{0}C provided an increase in number of opened eyes, suppression of apical dominance, earlier and more uniform emergence of seedlings, and the formation of a larger number of stems and tubers per plant. As a result, the yield of potatoes after treatment with ethylene increased depending on the variety and growing conditions up to 19.0%. We also found a more uniform structure of the crop in the aftereffect, which increases the efficiency of growing potatoes as raw materials for industrial processing, as well as for seed purposes.

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