

Development of maize hybrids for production and economic growth in the northern midland and mountainous region of Vietnam

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Abstract:

Maize is an important crop in the northern midland and mountainous region of Vietnam with the area of 406.1 thousand hectares, accounting for 45.8% of the whole country. In order to exploit the potential and advantages for developing sustainable and highly valued maize production, the program on development of maize hybrids for production and economic growth in the northern midland and mountainous region of Vietnam in accordance with the Government policies and the Ministry of Agriculture and Rural Development's directions on sustainable agricultural development strategy has been successfully implemented in which newly released maize hybrids developed by Maize Research Institute (Vietnam Academy of Agricultural Sciences) with high yield, good quality, good resistance and over-all advanced technologies were accordingly introduced in rainfed based maize areas of larger scale. The program partly contributed to improving the grain yield from 1.5 tons/ha in the early 1990s to 4.99 tons/ha in this region that played an important role not only in maize production development but also in national food security and environmental protection as well.

Keywords: economic growth, maize hybrids, mountainous region, production.

Classification number: 2.1

1. Introduction

Maize (*Zea mays* L.) is one of the more important food crops, and is used as a main raw material for feedings in Vietnam [1, 2]. With achievements in maize research and development based on integrated cultivating technologies, Vietnam's maize production has continuously developed with a rapid increase in grain yield of 4.99 tons/ha and the production of 4.42 million tons in 2022 compared to 1.5 tons/ha in the early 1990s [3].

To sustainably develop maize production on the basis of improving the quality, the added value and competitiveness of maize products in the market, and the programs of developing maize hybrids for production and economic development in Vietnam's mountainous provinces, based on product value chain should be needed that significantly contribute to a sustainable agriculture development and ecological environmental protection which is targeted to increase the income of local people in mountainous and remote areas [4].

The northern midland and mountainous region has great potential and advantages for developing

sustainable maize production, achieving high economic efficiency along with the value-added chain. However, the current maize yield in this region is quite low, 4.16 tons/ha equivalent to about 83% compared to Vietnam's average maize yield [3]. Because of that, Resolution No. 96/NQ-CP authorized by the Government dated 1 August 2022 states that the socio-economic development and national defense for northern midland and mountainous region by 2030 and vision towards 2045 must be implemented with the sustainable development of agricultural production suited to the chain of economic regions, in which maize is considered as a significantly beneficial for the region and should be paid great attention to, especially the overall application of maize hybrids to be effectively cultivated in climate change conditions with properly integrated farming technologies must be accordingly prioritized [5].

On the basis of scientific achievements obtained from the research and development of maize hybrids for production in combination with experiences that resulted in the large-scale increase of maize production in the whole country over the past 50 years, the Maize Research Institute of Vietnam (MRI) has proposed and is approved

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for implementation of the program titled "Development of maize hybrids for production and economic growth in the northern midland and mountainous region of Vietnam". The aim of the program is to partly contribute to sustainable agricultural development, improve socio-economic efficiency, protect ecological environments and promote agricultural value chains based on the overall evaluation of effectively advanced technologies applied in shortening and breeding maize hybrids with high grain-yield quality, good tolerance to stresses and adaptability to rainfed based maize areas without active irrigation systems in the northern midlands and mountainous provinces. And, what is more, the application of synchronous technologies aimed to improve economic efficiency and reduce greenhouse gas emissions during maize production should accordingly be addressed.

As a review on effects of the program on development of maize hybrids on production and economic growth in the northern midlands and mountainous provinces as well as major solutions given for developing maize production in the region, the research method presented is based on scientific analysis of data and information officially published on prestigious sources of General Statistics Office of Vietnam, Vietnam Ministry of Industry and Trade and etc. in according with the system of laws on the sustainable Agriculture and Rural Development including maize for the northern midlands and mountainous region, approved by the Government and the Ministry of Agriculture and Rural Development.

2. Current situation of maize production and development in the northern midland and mountainous region of Vietnam

The northern midland and mountainous region plays an important role in the national socio-economic development, defense and security. The whole region covers a total area of about 116,898 km², accounting for 35% of the country's natural land massy, including 14 provinces (Ha Giang, Cao Bang, Lao Cai, Bac Kan, Lang Son, Tuyen Quang, Yen Bai, Thai Nguyen, Phu Tho, Bac Giang, Lai Chau, Dien Bien, Son La, Hoa Binh) and 21 western districts and one town of Thanh Hoa and Nghe An provinces are involved with a population of 13.02 million, accounting for about 15.2% of the country [3].

Up to now, the region's potentials and advantages have not been effectively exploited, the agricultural value chain

has not been accordingly implemented and promoted among provinces in the region, resulting in still low development of regional economy as indicated by a low average gross regional domestic product (GRDP) of 63 million VND per year in 2022 compared to 95.6 million VND per capita of Vietnam's average GDP equivalent to 4,110 USD [3].

Maize has been considered an important crop for the economy of the northern midland and mountainous regions, an area of 406.1 thousand hectares is now cultivated, accounting for 45.8% of Vietnam's maize area that produces 1,688.9 tons annually [3]. The achievements in maize development program is mainly caused by the utilization of high-yielding, well-qualified maize hybrids resulting from research institutions that have significantly contributed to food security and economic development of the region for more than the past 30 years.

The northern midland and mountainous region are considered as the largest maize area in Vietnam where maize hybrids developed by MRI such as LVN10, LVN885, LVN092 and others of foreign companies such as NK7328, NK6253, CP511 have been commonly cultivated. Moreover, the synchronous application of cultivating technical packages in maize production has also improved the potential productivity of varieties and increased economic efficiency by 15-25% for maize farmers in the northern provinces [6]. As a matter of fact, different programs related to maize studies have been proposed and successfully implemented in the past decades involving research into improving maize-based farming systems on sloping lands in Vietnam [7] as well as post-harvest seed preservation technology in maize production [4].

It is also emphasized that timely policies issued by the Government concerning maize production are closely linked to the development of the agricultural extension system and have significantly contributed to creating a main motivation for the formation of a commodity maize industry, including largely concentrated maize areas in Son La province playing an important role in improving economic efficiency and developing sustainable maize production in the scope of the value-added chain under regional integration. Of the above mentioned policies, The following have been effectively implemented:

1) Agricultural development towards green, sustainable and comprehensive development in the northern midland and mountainous region according to the Resolution No.

96/NQ-CP dated 1 August 2022 on the Government's plan of action to implement the Politburo's resolution on orientations for socio-economic development and defense-security maintenance in the northern midland and mountainous region by 2030, with a vision to 2045 [5]. The orientation towards forming sectoral value chains and regional products such as the agricultural product processing centers in Son La province; The development of regional agriculture aimed to produce highly valued and safe specialized commodities in the scope of organic and green production with an appropriate scale.

2) The sustainable agriculture and rural development strategies for the period 2021-2030 with a vision towards 2050 approved by the Government according to the Decision No. 150/QD-TTg dated 28 January 2022, clearly clarified in crop production sector that takes advantages for reasonably developing less advantageous crops for processing and domestic consumption (maize, cotton, tobacco, subtropical fruits and vegetables, soybean) [8].

3) The Decision No. 915/QD-TTg, dated 27 May 2016 of the Prime Minister on policies for supporting the shift to maize production from rice cultivation, including the northern midlands and mountainous region [9].

In the light of the above-mentioned directions, the shifting to highly valued crops including maize and forage particularly from rice cultivation of lowly added value in Lao Cai province in the scales of the implementation of the Decree No. 62/2019/ND-CP dated 11 July 2019 by the Government amended some issues of the Government's Decree No. 35/2015/ND-CP on 13 April 2015 has achieved successes resulting in raising economic efficiency and improving living standard of local farmers that were reported in documents concerned in 2022 [10].

Apart from, the favorable factors of weather and soil conditions, this region is also facing many challenges indicated by insufficient quantity of agricultural laborers that are mainly lowly trained, ethnic minorities with limited capacity of investment. In addition, the strongly separated topography, the incomplete system of transportation and the lowly utilized mechanization caused by high slope cultivated area are considered as great difficulties for rainfed-based maize production in the region [11]. Because of that, the average yield in the whole region is quite low, estimated to be about 83% compared to Vietnam's average yield during the period of 2018-2022 [3].

Table 1. Maize area, yield and production in the northern midlands and mountainous region in the period of 2012-2022.

Year	Area (thousand ha)		Grain yield (quintals/ha)		Production (thousand tons)	
	NMM	Vietnam	NMM	Vietnam	NMM	Vietnam
2012	502.0	1.156,6	36.7	43.0	1,844.0	4,973.6
2018	455.9	1.032,9	39.5	47.2	1,801.5	4,874.1
2019	435.2	986.7	39.5	48.0	1,720.9	4,731.9
2020	426.4	942.5	40.3	48.4	1,716.5	4,558.2
2021	414.4	902.8	40.9	49.3	1,695.7	4,446.4
2022	406.1	887.0	41.6	49.9	1,688.9	4,423.2

NMM: Northern midlands and mountains region. Source: General Statistics Office of Vietnam, 2023.

Data presented in Table 1 shows that maize yield in this region has increased continuously resulting from the utilization of new maize hybrids with improved resistance, adaptation to climate change and the overall application of advanced cultivating technologies in large-scale maize production. It is, however, obvious that the maize area has decreased in recent years from 502 thousand hectares in 2012 to 406.1 thousand hectares in 2022. The crop conversion programs of provinces are regarded as a main cause for this situation.

According to the US Department of Agriculture (2023), the demand for maize of Vietnam would be increased up to 14.5 million tons in the 2023/24 crop year [2] whereas 4.426 million tons could be annually reached in whole country including 1.69 million tons produced from the northern midlands and mountainous region, accounting for about 38.2% of Vietnam's maize production [3], much lower than the requirement. Vietnam imported 10-12 million tons of maize per year equivalent 2.12-3.33 billion USD in the period 2018-2022 (Table 2). In the first 7 months of 2023, the quantity of 4.28 million tons of maize with the value of 1.4 billion USD was imported. On the other hand, shipping being the main transportation mean of imported maize was more expensive, which made maize prices significantly increase to 10,300-10,500 VND/kg in March 2022 [12]. In order to have enough raw materials used for feeding livestock while accordingly reducing the quantity of maize imported, the policies concerned to sustainable maize production for gradual replacement of lowly valued and disadvantageous crops must be suitably issued and implemented. The northern midlands and mountainous provinces regarded as one of the more important regions for maize cultivation in Vietnam should paid more attention to.

Table 2. Vietnam's imported maize quantity and value in the period of 2018-2022.

Year	Imported quantity (million tons)	Increase/decrease in quantity compared to the previous year (%)	Value (billion USD)	Increase/decrease in value compared to the previous year (%)
2018	10.18	31.8	2.12	40.9
2019	11.5	13.7	2.3	10.3
2020	12.07	5	2.39	2.8
2021	10.03	-17.0	2.88	20.6
2022	9.57	-4.5	3.33	15.6

Source: Vietnam Ministry of Industry and Trade (2018-2022).

3. Achievements from the research and development of maize hybrids released by MRI in the northern midlands and mountainous region of Vietnam

With the function of a research institute in breeding and transferring maize in Vietnam for more than 50 years, 108 new maize hybrids were developed by MRI and certified by the Ministry of Agriculture and Rural Development in which 69 maize hybrids were officially recognized as national varieties e.g. LVN10, LVN4, LVN99, LVN61, VN8960, LCH9, LVN885, VS36, LVN092, VN5885, LVN17, HN68... Up to now, the property rights of 15 maize hybrids with the price of 150,000 to 300,000 USD each were transferred to business companies and organizations. The quantity of maize hybrids developed and released by MRI annually accounts for about 25% of the hybrid seed market share in Vietnam, 500-600 tons of which were directly produced and transferred by MRI itself which saves 1.0-1.2 million USD for producers because of low seed price, about 2 USD/kg lower than foreign companies [4].

3.1. The research and development of grain purposed maize hybrids used for production and economic development in the northern midlands and mountainous region

Aimed to develop maize production in accordance with highly valued chain in sustainable agricultural production in the northern midlands and mountainous provinces based on the processes of innovation, technological and scientific application and cooperation in maize production, MRI has successfully studied and developed new maize hybrids of high economic value to be used effectively in the Northern mountainous provinces [4].

Realizing that the cooperation programs with business organizations should be a good method for advanced technology transfers of large-scale maize production, MRI has closely cooperated with various seed companies to transfer 13 maize hybrids for maize production and development in the northern midlands and mountainous region. It is also emphasized that the maize hybrids by MRI cost only a half compared to imported ones resulting in saving 8-9 million USD annually [13].

3.2. The research and development of green forage maize hybrids used for production and economic development in the northern midlands and mountainous region

The Decision No. 1520/QĐ-TTg of the Prime Minister on approving animal husbandry development strategy for 2021-2030 and vision for 2045 where total meat production should be obtained at 6.0-6.5 tons with a growth rate from 4% at present to 10% until 2030 whereas the scale of beef cattle herds from 6.5 million to 6.6 million individuals, dairy cattle herds from 650 thousand to 700 thousand individuals targeted for milk production of 3 times higher quantity than at present [14]. It is obvious that a big amount of animal feed must be accordingly supplied, especially in the dry season and winter in northern Vietnam. According to the Department of Livestock Production (2020), an amount of 27.6 million tons of forage and ensilaged maize is needed for cattle feeding annually, much higher than the forage maize quantity produced in whole country [15].

To meet the demand of feed for livestock in accordance with the animal husbandry development strategy up to 2030, 0.5 to 1.0 million hectares of land for growing grass and animal feed crops is necessary whereas about 50 thousand hectares of maize cultivated for green forage and silage is now available with a biomass yield of 120-150 tons/ha/year [16], therefore green feeds for domestic livestock requires importation.

In this situation, MRI has tried its best to develop forage maize hybrids like DH17-5, VN172 and maize grain-purposed ones with higher biomass yields e.g. TM181, LCH9, CS71 and complete cultivating technologies in the form of circular economy models cooperating with business organizations such as Binh Dien Fertilizer Joint Stock Company and Loc Troi Group [17].

Research results of MRI showed that growing forage maize in the northern midlands and mountainous region gives a lot of advantages indicated by not only limitation of weather risks that affect maize productivity and

quality negatively but also production of more harvests than grain-purposed maize cultivation because harvest cycles are between 75-90 days of biomass maize for the usage of green forage and silage. The utilization of land is, therefore, effectively improved with 4-5 harvests a year. In addition, the forage maize cultivation reduces production costs remarkably resulting in improving the income for growers (15-20% higher than grain-purposed maize production and 2.5-3.0 times higher than rice cultivation). The above-mentioned advantages make maize production in the northern midlands and mountainous region more and more sustainable [15, 18, 19].

3.3. The research and development of specialty maize used for production and economic in the northern midlands and mountainous region

Along with the development of processing technology and cooperation among economic regions, the recent demand of maize used for special purposes including foodstuff products in Vietnam has been growing that prevails good opportunities for specialty maize production including waxy corn, sweet corn and baby corn. With the function of research and development on maize, MRI has successfully developed plenty of specialty maize hybrids such as HN68 (NL5), VN559, G828 (NL147), Waxy8 (TG10) for sustainable production and economic development, partly contributing to the economic development in the northern midlands and mountainous region [4].

In summary, the national program of maize hybrid development has played a significant and important role in the direction of highly valued sustainable maize production in the northern midlands and mountainous provinces of Vietnam indicated by the following issues:

1) To contribute to improving economic efficiency and living standards of local farmers in the Northern mountainous areas through the application of maize hybrids with high yield, improved resistance and high adaptation to climate change.

2) To initially construct agricultural value chain in maize production with high economic efficiency from feed-specific maize hybrids such as green forage, silage, raw materials of feed processing industry for livestock and aquaculture industries to produce meat, milk, eggs or other highly valued specialty maize hybrids used in the foodstuff industry such as waxy corn, sweet corn and baby corn hybrids.

4. Some main solutions for developing maize production in the northern midlands and mountainous region

Currently, maize production in the northern midlands and mountainous region is facing lots of difficulties caused by climate change condition that has a negative influence on the growth and development of maize, especially for rainfed based maize cultivating system. In addition, lowly applied mechanization in most areas makes maize cultivation in the region difficult to form a stably market-oriented production chain with low competitiveness compared to maize products imported from abroad as well as other highly valued crops.

To sustainably improve the maize production in the above-mentioned situation, an overall solution involving properly planned projection for maize cultivation areas in combination with effectively and synchronously applying the introduction of advanced technologies and sustainably issuing policies must be paid great attention to, to establish sustainable and valuable production of maize in the northern midlands and mountainous region.

4.1. Selection and projection of proper areas for maize cultivation

As predicted by USDA, an amount of 14.5 million tons of maize grain should be targeted in the 2023/24 year [2], the area planned for maize cultivation is considered as one of the most important solutions is, therefore, in focused on especially in the northern midlands and mountainous region and regarded as the biggest maize production centre in the country. In order to ensure and improve the sustainable maize production with highly added value, closely linking market-production combination and climate change adaptation, the Decision No. 150/QD-TTg dated 28 January 2022 on approving the sustainable agriculture and rural development strategies for the period 2021-2030 with a vision toward 2050 was approved by the Government [8], in locally advantageous conditions it should be accordingly availed for the development of less advantageous crops such as maize, cotton, tobacco, subtropical fruits and vegetables, soybeans to be processed and consumed domestically.

The scheme on “Development of agriculture in some western provinces in the northern midlands and mountainous region towards increasing added value and sustainable development until 2025, with a vision to 2030” issued by the Ministry of Agriculture and Development Rural stated that an area of about 222 thousand hectares to produce about 943 thousand tons of maize should be maintained by the year 2025 while about 228 thousand

hectares and around 1.06 million tons respectively will be targeted for the year 2030. The sandy and alluvial soils must be prioritized for maize cultivation in the forms of rotating and intercropping with other crops on which the regions of commodity-oriented maize, sweet and waxy corn for processing and forage maize for livestock will be properly established [20].

4.2. Scientific and technological solutions

4.2.1. Solutions for breeding and development of maize hybrids

- To invest and upgrade research facilities and equipment involving infrastructure concerned to meet requirements for maize breeding program such as genetics, molecular marker and cell technologies in combination with human resource training, especially highly qualified experts who can master and apply advanced technologies and integrate internationally.

- To strongly boost the study on breeding and developing Vietnam's maize hybrids used in the northern midlands and mountainous region aimed to active preparation of maize hybrid seeds at low prices (3-4 USD/kg), resulting in reducing foreign currency for importing high-priced seeds from multinational companies (7-9 USD/kg). The grain yield of domestic maize hybrids is up to 10-12 tons/ha in the condition of intensively applied cultivation, 5-7 tons/ha in rainfed areas, with high tolerance to heat and drought, adaptation to climate change and meeting the demand of various markets.

- To strengthen and diversify domestic maize hybrids, especially forage and specialty maize, towards sustainable development and product diversification in maize value chain of the region.

4.2.2. Technical solutions for sustainable maize cultivation

- To develop a set of maize hybrids suitable for sub-regions or locations in the northern midlands and mountainous region to effectively exploit their potential in appropriate cropping structure and crop seasons.

- To complete packages of advanced technologies including crop season determination, land preparation, fertilization, sowing, taking care, harvesting, post-harvest treatment, processing and preservation that need synchronous application in maize production in the northern midlands and mountainous region with the aim of improving productivity, efficiency and increasing maize value chain.

- To strengthen mechanization application in maize production in the region as much as possible.

4.2.3. Solutions for improving product quality and reducing post-harvest losses

- To suitably reorganize the maize production with sufficiently scaled area and use the few hybrids on applying the similar procedure of cultivation, processing and preservation to produce uniformly and highly valued commodities.

- To improve the facilities of harvesting, processing and preservation based mainly on strengthening mechanization application in large scale of maize production in the region.

4.3. Solutions of policies related to investment, cooperation and development of sustainable maize production in the northern midlands and mountainous region

4.3.1. Solutions for upgrading infrastructure investment concerned to maize production in the region

- To strongly invest in upgrading transportation system in important locations of maize production in the region aimed to facilitate favorable conditions for transportation of materials, fertilizers and commercial maize products resulting in reduction in the cost of production and improvement in product quality.

- To develop irrigation systems for major areas of maize cultivation. As calculated, about 80% of the maize cultivated area in this region is under rainfed condition at present.

- To strengthen public-private cooperation and to call upon capital invested for maize production in the region, firstly focused on large-scale maize processing plant systems in accordance with regional planning projection and raw material consumed chain.

4.3.2. Solutions on governmental policy

- To effectively implement the contents of related policies issued and approved by the Government and highly ranking organizations as well especially the Decree No. 98/2018/ND-CP dated 5 July 2018 on incentive policy for development of linkages in production and consumption of agricultural products, including maize in the northern midlands and mountainous region [21].

- To establish production linkage-based large-scale production demonstrations in which mechanization utilization, overall advanced technology application of

cultivation, harvest, processing and preservation aimed to reduce production costs and improve product quality should be presented.

- To closely link product consumption with raw material localities, keeping prices stabilized and profits harmonized and risks shared with farmers.

- To establish market-related information systems and boost trade promotion through propaganda targeted for the development of stable market for maize products.

- To issue policies concerned to call upon businesses for investment to strengthen R&D activities and maize production as well.

4.3.3. Solutions on policy mechanisms

- To issue the policies related to regional advantage-based planning projection for sustainable, largely concentrated and highly valued maize production closely linked with consumption markets in and out the region.

- To issue policies on supporting local farmers in crop shifting structure directed to increasing maize area and reducing post-harvest losses and improving product quality and value added as well.

- To issue policies on enhancing the capital investment in infrastructure construction, maize research and development towards increasing mechanization in maize production in the region.

5. Conclusions

The program of development of maize hybrids for production and economic development in the northern midlands and mountainous region of Vietnam has played an important role in improving economic efficiency in maize production and partly contributed to establishing a maize based sustainable, highly valued agricultural chain through the introduction of high yield maize hybrids well adapted to climate change, developed and released by MRI, and the overall application of advanced technologies used in maize cultivation.

In the scope of the program targeted for the sustainable and highly valued maize production, the cooperation among farmers, scientists, businesses and state management agencies was strongly strengthened that takes an important part in ensuring food and nutrition security and poverty reduction in mountainous regions .

With the implementation of the above-mentioned program under the direction of the Government and the Ministry of Agriculture and Rural Development concerned

to sustainable agricultural and rural development strategy, the research capacity of MRI is significantly improved particularly in the field of maize breeding and development in a large scale.

Thus, with maize hybrids with good tolerance and high yield and technical packages in terms of economic efficiency, suitable for maize production, the program on development of maize hybrids for production and economic growth in the northern midland and mountainous region of Vietnam has upgraded the maize yield of 3.67 tons/ha in 2012 to 4.16 tons/ha in 2022, partly contributing in national food security and environmental protection as well as production development and economic growth in this region.

In order to ensure the sustainable development of maize production in the northern midlands and mountainous region of Vietnam, meeting requirements of the market, international integration and added value of agricultural products, the overall policy including plan projections of maize planted area, stronger investment for R&D activities in maize hybrid development programs, more funding resources for forage and specialty maize hybrid breeding and specific funds for processing industry of maize products under particular and public-private sector cooperation should be paid more attention to and synchronously implemented in the region.

CRedit author statement

Nguyen Xuan Thang: Reviewing, Methodology, Formal analysis, Writing, Editing; Nguyen Chi Thanh: Data collection, Writing.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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