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The Intensity of Agriculture in the Covid-19 from Indonesia – A Systematic Literature Review

Abstract: The agricultural sector will surely crushed if there is no acute attention from the government in an agrarian country. As a reflection, the importance of the agricultural sector, which produces foodstuffs in the food security agenda in a difficult situation. The objectivity of this article is to present the existence of the agricultural sector and strategic aspects to support the agricultural sector in Indonesia so that it can cope with the Covid-19 pandemic. To clarify the presentation, we use the SLR method, which will determine the extent of the fate of the agricultural sector with comparisons from previous studies relevant to this. The results of the review prove that the agricultural sector in Indonesia, especially in food, is almost 70% of smallholder agriculture. With this people's farming model, we need to conclude that we will maintain as long the food reserves in the community as the farmers keep planting. Because of this, the things that need to be done are to provide stimulus to farmers and guarantee the purchase of the products or commodities produced. In certain cases in several regions, the price of agricultural commodities declines and demand is low because thousands of restaurants and restaurants have closed, and reducing their sales capacity. ~~The availability of data and studies relevant to this article is an obstacle. In addition, the limitations of the SLR method only describe the phenomenon of the agricultural sector problems when the Covid-19 occurred in Indonesia in a broad outline without empirical findings.~~ Abstract is too long. Avoid 'sentences' that have the potential to cause double perception. Authors should include future contributions and agendas at the end of this section (Normally it only contains 150-200 words) .

Keywords: Food security; Farmers; Development model; Strategy; Agribusiness

1. Introduction

It well known the ASEAN region for its agrarian base which consequently the growth of almost all Indonesians, hence the need for government attention to a resilient agricultural sector. Therefore, one sector that supports the Gross Domestic Product (GDP) is the agricultural sector (Wahyuningsih et al., 2020).

As the Novel Coronavirus (Covid-19) continues to spread around the world, it is important to respond to existing and affects on the agricultural sector, both from a food supply and demand perspective (Alhawari et al., 2021). It is imperative to ensure that global and national food supply chains continue to function in ensuring the availability of food supplies, preventing food crises in countries already experiencing food security and nutrition challenges, and reducing the overall negative impact of the pandemic on the global economy (Darma et al., 2020).

Especially for Indonesia, this country also relies heavily on the agricultural sector. This means that farmers play a very important role in the entire national economy (Rokhani et al., 2020). The workforce absorbed in the agricultural sector shows this. Farmers and agriculture are the major bases of Indonesia's economy. If only this agribusiness system could get attention from the government, then Indonesia could be independent to fulfil the population's foodstuffs (Wijaya et al., 2020; Roy et al., 2019). The government's attention includes supporting the agricultural sector in the fields of research and technology that are commensurate. It would be better if there is no big attention from the government, don't expect this sector to develop (Rozaki, 2020).

In mid-1997, ASEAN countries had been hit by a regional economic crisis caused by currency depreciation from the influence of the US dollar (Sunderlin et al., 2020). In its journey, Indonesia was the worst affected among other countries in ASEAN. Evans (1998) states that the collapse of the Indonesian economy in the last few decades is the most dominant in any economy, which refers to the global market orientation. However, the existence of the agricultural sector at least still supports the sustainability of the Indonesian economy, even though other sectors have experienced a recession.

Until now, the global economy is still showing unfavorable conditions. The global trade war involving two economic giants (the United States and China) in recent times has also generated negative sentiment towards the economies of countries around the world, including Indonesia (Darma et al., 2020). The Central Bureau of Statistics of the Republic of Indonesia (2020) noted that in the third quarter of 2019, Indonesia's GDP grew 5.02% (year on year). This was relatively slow when compared to the first and second quarters of 2019 because the growth reached 5.07% and 5.05%. Behind the sluggish conditions of the world economy, we believe the agricultural sector to be a hope of maintaining the Indonesian economy (Andri, 2019).

The development of the agricultural sector needs special attention from the government because Indonesia can become a developed country, even though it must be based on agriculture. If this can do, countries close to Indonesia will depend on the aspect of foodstuffs. New Zealand and Vietnam are examples of countries that are developing their economies based on agriculture. In this article, we try to review the extent to which the intensity of the agricultural sector in Indonesia is facing Covid-19, which has caused the collapse of the global economy. The structure of the paper has not been described. The mechanisms in each point (chapter) should be detailed.

2. Literature Review

2.1 Agricultural Development

The effort to develop an agricultural perspective in the first stage signifies abandoning the pre-modern view of agriculture which embraces the needs of society in the traditional era. From the historical context, problems in agricultural development do not mean changing the static-based agricultural sector into a modern dynamic sector, but emphasizing the acceleration of agricultural productivity and the results of growth that can be in line with economic growth in other sectors by modernizing forms. Ideally, agricultural development theory is also a link between the dynamics of agricultural growth and the sources of economic growth, so that it changes form from the emergence of output growing at the level of 1% of those who traditionally farm to 4.0% or more per period (Ripoll et al., 2017; Zyl, 1989; Dercon & Gollin, 2014).

Dramatically, the role of the agricultural sector changes in line with development thinking patterns. The dualistic view states that the agricultural sector can suppress, even the role of the industrial sector needs to be protected to supply surplus labor to modern sectors such as services and finance. In fact, Mellor (1995), Mosher (1966), and Myrdal (1968) strongly support the existence of agricultural development, which highlights that the life cycle will not be sustainable by impoverishing those who are highly dependent and working in the agricultural sector. It should note, neoclassical forces also explain the relatively fast expansion through the manufacturing sector to support it (Jorgenson, 1961). On the one hand, Mellor & Johnston (1984) intensively explain how investment flows for the agricultural sector can stimulate an integrated economy to reduce poverty levels by absorbing employment, high real wages, and affordability of food prices (Hanif et al., 2019). For non-agricultural products, they can develop it to support policies that are pro-economic surplus, so that it used them for production input (capital).

The participatory agricultural movement in the 90s made rural areas able to produce community-based development. We transform this movement through an approach aimed at local government through its authority and empowering local communities who have the resources to take control of agricultural development (Kheiralla et al., 2003). The authentic form of agricultural development is real participation, technical health, sustainability, and increased accountability. Their participation is real by involving stakeholders to analyze and include the role of citizens for each policymaking. They packaged decisions on agricultural sector development with full representation through tight budget constraints and shared interests. The agricultural community also has strict control over program design, resources, implementation, and selection.

The accountability dimension will slowly shift the horizontal emphasis, where members who are members of the community deserve to be empowered to encourage improvement by taking firm action against other wrong members. Technically, community sustainability implies proven methods in various environmental and social areas. Other factors such as assets, finance, social and environmental sustainability also needed. The result is policies that are political in line with the dominant policy reforms for agricultural development. Before being widely adopted, this should consider institutional design and principles based on previous case studies (Krueger et al., 1988).

2.2 Agricultural Sector Economic Growth

Economists realize that support for sectoral transformation, which aims to mobilize resources, accompanied the role of economic growth in a country and absorbs labor in the agricultural sector to switch other activities (Bowles, 1986). The nature of this transition presents a two-way (causal) relationship, thus attracting debate and generating long controversy. The discussion focused on whether it balanced an increase in agricultural productivity with the transformation of the industrial revolution?. Various observers in development economics have highlighted foreign investment which gives priority to industrial development or agricultural development. In fact, Syrquin (1988), Chenery & Syrquin (1975), and Kuznets (1966) do not consider this. Initially, they presented structural transformations in the agricultural sector over several periods, with empirical studies shaping patterns of sectoral change across countries.

So far, a report from the World Bank (2009) explains that the agricultural sector has contributed to economic activity in developing countries, while for poor countries, this sector has contributed around 25% added value. The agricultural sector also has a big share in playing exports to developing countries through food and non-food crops. For case studies in several countries, the export value of raw agricultural commodities reached 15%–30% of total GDP (Gollin, 2010).

Figure-1. Transformation of sectors in economic development

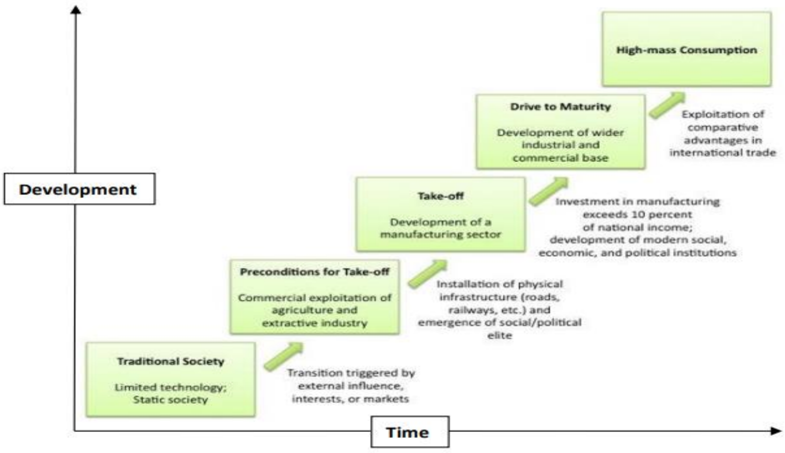
	Primary Sector	Secondary Sector	Tertiary Sector
The Traditional Society	Vast Majority	Very Few	Very Few
Pre-conditions for Take Off	Vast Majority	Few	Very Few
Take Off	Declining	Rapid Growth	Few
The Drive to Maturity	Few	Stable	Growing Rapidly
High Mass Consumption	Very Few	Declining	Vast Majority

Source: van Arendonk, 2015.

Figure 1 presents the role of the agricultural sector in three phases to support economic growth. Rostow (1960) adds that the agricultural sector influences other sectors such as industry from time to time, where development on economic growth in a country can take off.

Previous empirical studies reveal that there is a lack of consensus and conflicting evidence about the impact of the agricultural sector on economic growth. Several studies also explain agricultural development in a country as an absolute requirement to drive economic growth and industrialization, so other researchers also argue the opposite and this is a long debate. Schultz (1964), Awokuse & Xie (2014), and Gollin et al. (2002, 2007) concluded that aggregate economic growth highly depends on the development of the agricultural sector.

Figure-2. Phase on economic development



Source: van Arendonk, 2015.

The development of the economy explains the differences between the five phases of economic growth over time developing to the ultimate stage (high mass production) which represents full achievement. Phase 1 (traditional society) describes the subsistence of agriculture and almost the entire economy depends on the primary sector. In phase 2 (a prerequisite for take-off) presented the expansion of labor-intensive agricultural products through capital savings. In phase 3 marked the emergence of a developing manufacturing sector with a transition from the primary structure to the secondary structure, resulting in a shift in the economy (see Figure 2).

Appreciation of agricultural productivity is important in the transition process to the next stage. Johnston (1970) underlines the role of the market in broad terms to revitalize commodities from developing industrial sectors, so that they can generate investment for new leading sectors. In relation to the emergence of basic sectors outside of agriculture, the role of technology is important in this process. The emergence of new leading sectors through signals of secular decline (primary sector).

2.3 Agribusiness

The emergence of the concept of “agribusiness”, was first expressed by Rust (1957) who explained three different but interdependent spheres in the global food system. The three areas are producers of agricultural commodities, suppliers of agricultural inputs, and institutions related to the marketing of food products (Harrison & Desmond, 2011).

Yusi & Idris (2016), Arumugam et al. (2017), and Ramukumba (2013) reveal that limited financial capital can lead to agribusiness failure. So far, financial initiatives are available to help business people, including loans. Their income and raw material costs can fluctuate from time to time because of economic uncertainty. These factors will hinder their expansion of innovation and business development.

The most dominant obstacle in agribusiness is ethical issues because people need to remind themselves and the potential that emerges is normal because of the market activity. Ethical and economic values coexist since humans are born and those who depend on business activities so that they last a long time in society. This is very important because one can see and avoid various kinds of problems that arise regarding ethics in the market (Kirsten, 2003; Harrison et al., 2019).

Entrepreneurial trends have fluctuated over the decades and are not merely theoretical, but focus more on a more practical direction. Agribusiness develops because it combines entrepreneurship and agricultural concepts. The occurrence of changes because of the economy, environment, and additional needs in the business world is consistent to maintain the economic dynamics that occur in the world. Mudiwa (2017) in his study refines entrepreneurial theory as an attempt to explain the relationship between human and market behavior.

2.4 Agricultural Technology

Technology plays a vital role in making many changes in all disciplines. Development economists suggest developing countries to adopt technology from developed countries in order to achieve economic growth (Feder et al., 1985). Aspects related to agriculture and food, they are also interested in seeing the extent to which the function of new technologies can increase food security and productivity. By nature, environmental economists are very concerned about how they can use new technologies for efficient management of the environment and resources (Tietenberg, 2000). In contrast, Kalaitzandonakes et al. (2018) revealed that industry and companies actually advocate technology, because its acceleration will reduce production costs and increase effectiveness, efficiency, and collective labor.

The basic technology for developing agriculture is an irrigation system. Water is a scarce resource in several countries. Rural policy schemes in the past developed irrigation infrastructure to ensure the availability of irrigation water based on the increasing demand for agricultural products (Chou et al., 2001). However, this expansionary policy incurred enormous investment costs, so that its impact was widespread on the consumption of irrigation water by the agricultural sector and there was a physical scarcity of resources. Policymakers and water users are seeking to give competitive attention to the problem of water scarcity for agriculture. The design of the use of modern irrigation technology is not only a discourse, but it needs to carefully designed as a solution for the long term (e.g., Chowdhury, 1984; Koundouri et al., 2006).

2.5 Agricultural Sector Economic Growth

They defined food security as the uncertainty or limitation of the safety and adequacy of food nutritional intake to get socially acceptable food (Anderson, 1990). Maia et al. (2020) consider food security to be a public health problem and is much bigger when it experienced by children. There is growing empirical evidence of the lack of attention paid to food security to negative human health outcomes from birth. This actually strengthens the relevance of his judgment in the period of life.

For example, in North America they define the term food security as a phenomenon closely related to the concepts of malnutrition and hunger. Since

1990, researchers have used a scale to measure hunger through qualitative interviews with people experiencing it. Radimer et al. (1990) classified hunger with four components, i.e. quality, quantity, psychological and social at the individual and household level. It based the reference to these components on the quality and quantity of accessible food, the psychological impact of navigation on a person's fear of insufficient food, and the way people interact socially to reach food. Until now, this concept remains relevant through the use of the term food security.

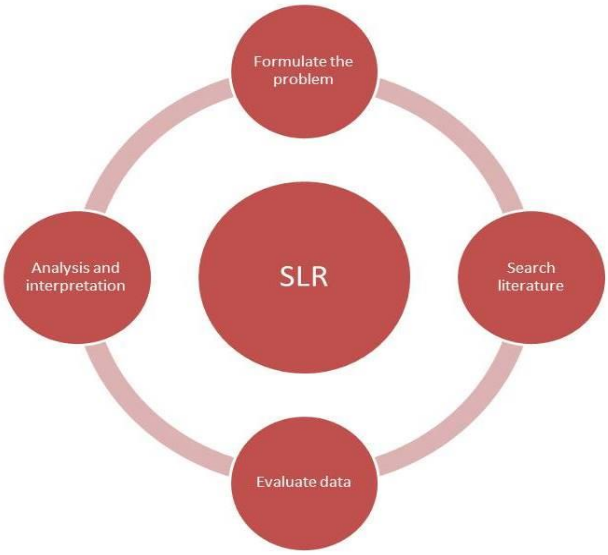
In the process of economic development, food security is an important component. In the last few decades, food security has increased, which shows agricultural productivity can reduce poverty levels. The correlation between food products and food security is very close because of government intervention (Chavas, 2016; Fogel, 2004; Barrett, 2010; Charles et al., 2010).

3. Methodology and Procedural

The Systematic Literature Review (SLR supports the presentation of this article). The SLR method is often used to study, identify, interpret, and evaluate several studies that apply to topics related to certain phenomena (Triandini et al., 2019; Wahono, 2015). SLR can also form a theoretical framework for a specific topic or field of study, explain definitions, keywords, and terminology, determine models and case studies that support the topic, and develop research (Wee & Banister, 2016). With this approach, we can carry a systematic review of journals out, because the process must follow predetermined steps. What are the advantages of the 'SLR' method? I did not get detailed information about this.

We try to provide criticism through interesting ideas and ideas from this article with a special topic concerning the intensity in the agricultural sector amid the Covid-19 outbreak. This shows that the writer understands the study area, knows the main issues, has the competence, ability, and background that is appropriate for the field. Of course, SLR must also be continuous with previous studies and how they relate to the discussion in this article. Grant & Booth (2019) add that there is a need for integration and conclusions about things that are known in the chosen study area, so that there will be references to other people to stimulate new ideas.

Figure-3. Stages in SLR



Source: Leite et al., 2019.

We presented the four components in SLR in Figure 3. The first component includes selecting topics that match issues and interests, and planning problems, so must have written completely and accurately. Second, we need to find literature relevant to the study, get an overview of the study topic, compile references and supported by the knowledge of the topic being studied, and cover or conclude from previous studies. In the third component, looking at what contributions to the topics discussed, looking for data sources according to the needs of the study because this is very important in terms of the composition of quantitative data. Then the fourth is to discuss the findings and summarize the literature.

4. Scheme and Discussion

Indonesia's economic growth projected to fall in 2020 because of the impact of Covid-19. Kuniawan & Santoso (2020) project that Indonesia's economic growth will reach 0.5%, while Susilawati et al. (2020) predict between 1.0% and 1.8%. Far beyond the economic growth seen in recent years, growth for Indonesia was 5%. Bank Indonesia (2020) also highlighted that the development of economic growth in Java Island could even fall more than the national level to -2.1% (pessimistic scenario) and 0.6% (optimistic scenario). As a result, various development agendas, such as poverty alleviation and increasing the Human Development Index (HDI) will experience serious disruption. They predict unemployment to increase from 8% in 2019 to 12% in the worst scenario.

This pandemic has multiple effects on various sectors of the economy. Analysis from the Indonesian Central Statistics Agency (2020) predicts that one sector that will badly affected is the tourism sector. Meanwhile, the economy of Bali Nusa Tenggara for example, during the first quarter of 2020 contracted by nearly 7% (the worst in all of Indonesia). This also does not include the impact of social restrictions because of the Covid-19 pandemic crisis, which only started in April 2020. The manufacturing and industrial sectors will massively affect.

Ravallion (2020) considers that the global manufacturing sector and industry will hit by a serious crisis if not handled. Likewise, areas with industrial bases in Indonesia such as Banten Province, DKI Jakarta Province, and West Java Province. So far, the agricultural sector will be the least affected compared to other sectors. A reflection of social restrictions will be relatively minimal in the agricultural sector, although there is still a risk of disruption of the supply chain and a decline in demand (Kusrini & Maswadi, 2021). Projections from The Economist Intelligence Unit also confirmed the relative resilience of the agricultural sector (2020) of the Indonesian economy for April 2020. When the Covid-19 outbreak took place, the growth of the manufacturing sector from 3.0% to -1.5% (corrected -4, 5%) and the service sector by 7.2% to 2.4% (corrected -4.8%), growth in the agricultural sector only revised from 4.1% to 3.2% (-0.9%).

Apart from the relatively small impact of social restriction, it is more caused by agricultural production centers, not in densely populated areas. The agricultural sector, especially food crops, naturally will not be as bad as other sectors when a crisis occurs. This occurs because of the low elasticity of demand for food crop agricultural goods. When the economy is experiencing a booming period, the demand will not proliferate. Likewise, when there is a recession, the demand will not decrease drastically. The history of crises that have occurred in Indonesia, for example, the 1997-1998 monetary crisis, has also left a record of the relative survival of the agricultural sector, even accommodating workers who lost their jobs in urban areas. Despite the monetary crisis, the agricultural sector could still grow positively at around 0.26%. In fact, national economic growth is collapsing up to -13.10%. Muliadi et al. (2020) explain that the agricultural sector also helped the Small and Medium Enterprises (SME) sector. The role of the agricultural sector as a buffer in times of crisis will repeated this year.

Likewise, the global crisis in 2008 which caused the collapse of the world financial system. The impact is paralysis in many sectors throughout the country. The rent has dropped European industrialized countries and several Asian exporters. However, Indonesia’s GDP in that year still grew by 6.1% against 2007. GDP growth in oil and gas even increased by 6.5%.

Figure 4 shows a reflection of Indonesia’s GDP from the agricultural sector during these 36 periods. The average GDP growth for Indonesia at the level of 17.03% with the lowest growth comparison in 2019 was 12.72% and the highest reached 24.25% in 1986. Inline big, this achievement has experienced a very significant depreciation considering that Indonesia is an agricultural country that can employ many people in this sector. For comparison based on 144 countries in 2019, the average economic growth in the agricultural sector is 10.46%. We used global ranking trends for the sector for comparison. It measured the importance of the agricultural sector for other countries and particularly in the economy in Indonesia as the added value of the agricultural sector to the percentage of GDP in aggregate.

If we trace the conditions in the GDP structure, the decline occurred in almost all sectors. We recorded only three sectors that showed positive growth (agriculture, industrial sector, and the construction sector). The agricultural sector even recorded a significant increase from 13.7% in 2007 to 14.4% in 2008. This phenomenon shows that performing the agricultural sector has a significant influence on the growth and resilience of the national economy. The positive performance of the agricultural sector in 2008 also refers to the record of the export-import trade balance. The volume of agricultural exports that year reached 29,287,752 tons (up 12.9%) when compared to 2007, which was 21,257,150 tons. We can also see interesting data from import activity in 2008. The volume of agricultural imports in Indonesia in that period fell by 20.9%. As a comparison in 2007, the import growth from 12,582,510 tons to 12,852,510 tons. In fact, in 2008, the overall imports of Indonesia actually increased (Yusuf et al., 2020).

Figure-4. The GDP share of agriculture in Indonesia, 1983-2019

Source: The World Bank, 2019.

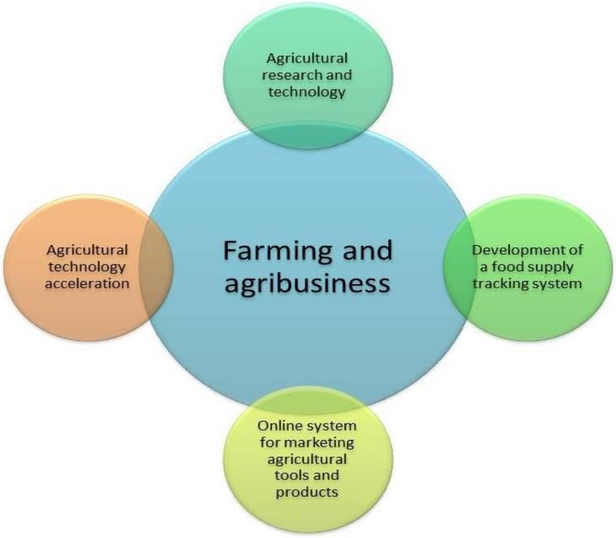
This shows that amid a slowing economy, Indonesian agricultural trade in the international market continues to progress positively despite food shortages. The threat of food scarcity occurs as the effect of the global economic crisis. Food scarcity is a situation caused by a decline in food exports to world markets. When the global market experiences food shortages, Indonesia should remain stable because the volume of exports increases along with the decrease in import volumes.

The performance of the agricultural sector is not only a food provider for Indonesia's 267 million people, but can also accommodate a large workforce, reduce poverty, and contribute significantly to improving the welfare of the community. Agriculture managed by the people has been independent for years, free from dependence on technology and aspects of capital.

Indonesia needs to fix the pattern of agricultural empowerment to increase the quality and quantity of produce in the agricultural sector to meet basic food needs. The first step that needs to be done is the provision of seeds, seedlings, cultivation techniques, and harvest and post-harvest technology. Empowerment patterns need to be done with good synergy from various sectors to develop agriculture. According to Yosi (2020), Indonesia has postponed trade in vegetables, animals, and fruits from China and other countries to prevent the Covid-19 outbreak.

Darma et al. (2022) and Abadega (2021) underline the things that are important to do so that the agricultural sector continues to exist from any situation and condition. We designed a model of an effort to revitalize the agricultural sector in this probability which refers to five stages covering agricultural research and technology, development of food supply tracking systems, accelerated technology adaptation, online systems for marketing agricultural tools and products, and packaging systems with technology (see Figure 5).

Figure-5. Agricultural sector support strategies



Source: Author's elaboration.

First, keep running the agendas in the agricultural technology research and development sector, especially those related to cultivation, crop protection, and agricultural digital systems. The goal is that the upstream aspects of agriculture can still support other sectors downstream. They made this commitment based on the concept of research and development, which is a long-term investment. As a result, research and development in the aspects of cultivated agriculture, crop protection, and digital systems remain in the corridor. However, this requires adequate budget adjustments because of the conditions of Covid-19. The most important thing is that it still achieved the main agendas in the agricultural aspect through this strategy.

Second, the continuation of ongoing research in the agricultural aspect through the development of a digital system to determine food availability. During this pandemic, mobilization in the field hampered, so we need a digital system to track food availability directly from anywhere. Of course, the distribution of food from upstream to downstream can still track effectively, efficiently, and even.

Third, we expect farmers to speed up technology adoption. By accessing information online and without direct intervention from extension agents provided by the government and the private sector, it can minimize problems such as pest and disease control. The role of farmers is very central because agricultural products are a necessity that must be available to the community.

Fourth, limited mobilization forces agricultural business actors to carry out innovation and creativity through digitization. Pandemic conditions have become increasingly promising in selling agricultural equipment and products. People are also looking for agricultural support tools because they have to work from home and like farming. Agricultural products that are sold online are a new alternative to divert boredom while at home. Agricultural products as plant seeds (cultivated and ornamental plants) or other agricultural products increase added value.

The combination of the concepts of the four elements provides added value for processed agricultural product entrepreneurs who expected to shift to automation in terms of the packaging process. This requires the packaging factory workers to be on vacation even though the business target must still be running. One solution in packaging processed products is through wholesale packages into retail packages. The level of people's income starts and adjusts their basic needs, of course, affecting their purchasing power in the market. The retail package makes it easy for people to keep buying agricultural products that the factory has processed.

5. Conclusion and Contribution

Through the model in this idea, there is an opportunity that will improve the welfare of the farmers. The opportunity for market expansion during the Covid-19 outbreak also intended to build sustainable agriculture. So far, Indonesia has not panicked too much about the food stock because it has a superior agricultural sector.

The conclusions in this article are certainly very relevant to several previous studies. In connection with the impact of Covid-19 on the agricultural sector in Indonesia, Olivia et al. (2020) and Caraka et al. (2020) informs that this pandemic has a very systematic effect on the Indonesian economy, so that in the short, medium and long term, the government needs to plan vital policies in anticipation of a food stock crisis. In addition, Rusdiana & Talib (2020) and Pulubuhu et al. (2020) explains the multiplier effect because of Covid-19 in Indonesia, in sequence, it can collapse the agricultural sector which is marked by the emergence of socio-economic problems such as hunger, poverty, unemployment, layoffs, and problems related to welfare.

So that farmers can carry out activities, as usual, they need education from the government on how to handle it in reducing the spread of Covid-19. The construction of posts that specifically deal with current conditions will ensure food and other staple goods run smoothly. In addition, the Indonesian government needs to speed up exports to strategic communities in supporting the sustainability of agriculture and the national economy. Then, it expected to develop agricultural markets in each region, optimize local food, coordinate logistics infrastructure, and e-marketing, so that these labor-intensive programs can achieved on target.

The implications of the study must be explained at the end of the 'conclusion', so that it becomes a limitation for further agendas.

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Competing Interests

The authors declare that they have no competing interests.

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The authors fully took part in this article. Contribution from Dr. Y.K is by generating ideas, developing concepts, determining objects of study, mapping problems on relevant phenomena, and looking for references (55%). Then, Mr. M.A.K and Dr. Z.I share 45% which includes the preparation of a study method or model, describing the findings, providing final conclusions, and policy implications as recommendations.

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Academic Research

Molecular Assessment of Established Clonal Propagated (*Morus nigra* L.)

Abstract: Mulberry (*Morus Sp*.) is one of the economically important trees cultivated for the tasteful fruits. In Saudi Arabia, Mulberry grown well and spread in different places such as Taif Province (El Shafa region), Eastern region; Al-Ehsaa Province and some southern areas.
Nodal explants of *Morus nigra* were clonally propagated *in vitro* for plant regeneration. Auxiliary shoot buds have been promoted in Murashige and Scoog (MS) media in a variety of cultural contexts. The largest number of shoots (13.00 ± 0.47) with an average length of 2.00 ± 0.47 cm were initially obtained from a medium containing 2.0 mg / L N6-benzyladin (BA) and 3% sucrose. Recurrent subcultures provided the highest number of seedlings (approximately 29.30) for excavation after the fourth passage. Seedlings were rooted in 1/2 MS medium supplemented with 1.0 mg / 1 indole-3-butyric acid (IBA). Successfully, about 90% of the plantlets acclimatized. Along with determination of the genetic variations between three mulberry genotypes including two cultivated accessions (*Morus alba*) and one wild genotype (*M. nigra*) utilizing inter-simple sequence repeat (ISSR) markers. Genetic variation and phylogenetic relationship of mulberry germplasm collection have been studied. All ISSR markers used in this study revealed higher genetic diversity was in the wild species comparing with cultivated species.
ISSR matrices reported that the mean genetic similarity coefficient was 0.7677 for all mulberry genotypes. Although some differences have been observed, much similarity has been obtained in dendrogram topology. Cluster analysis of the ISSR using UPGMA software revealed that wild species were genetically distinct. The correlation coefficients of similarity for the ISSR used are statistically important. The Principal Coordinate Analysis (PCA) for ISSR data also supports its UPGMA clustering. The average number of genetic variations recorded in mulberry genotypes was 0.287±0.096. Dendrogram (Un-weighted peer group method analysis) classifies mulberry accessions into two main groups; Admissions collected from western area of Taif, and the other comprised two sub-clusters including one isolate, i.e., *M nigra*, a collection from Al shafa. Contains access to another sub-cluster southwest regions of Taif, which belong to *Morus nigra* wild growing. These accessions of mulberry were found to be genetically similar from north and southwest Taif Province. These results have significant implications for improving the mulberry germ plasma characterization, conservation and investigates the genetic diversity among the mulberry species grown in Taif governorate and to establish a micro-propagation system as germplasm conservation to preserve the assets of local

Comment [i-[1]: Add other uses of Morus Sp. besides the savory fruit.

Comment [i-[2]: Add two relevant reasons:
1. Is Saudi Arabia the best place for Moris Sp. to grow, high production and the most savory taste?

2. As a comparison in which country or hemisphe does Morus Sp. also grow well?.

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mulberry and thus develops an easy and effective method to identify native genotypes in a limited space and time frame.

Keywords: *Morus nigra, in vitro* propagation, genetic distances, ISSR markers.

1.Introduction

Mulberry belongs to the genus Moras, which belongs to the genus Morse. Mulberry (*Morus* sp.) is commonly used to obtain silk for leaf feeding for silkworms. But the fruits of this species have an amazing ability to provide a variety of valuable industrial products. It is used in the food and pharmaceutical industry and opens new avenues for the industrial exploitation of mulberry fruits around the world. More than 150 species of mulberry have been reported, although their identity is still the subject of great debate. Conservation of all genetic resources, including cultivated and wild relatives, is essential. Traditionally, mulberry is propagated by cuttings and seeds. Mulberry growers often find it difficult to root the cuttings. Propagation by seeds is undesirable due to the huge diversity of plants due to cross-pollination. Tissue culture techniques such as micro-amplification provide a fast and reliable method to produce many identical plants in a short period of time. *In vitro* production of plants from auxiliary buds by different workers has been reported in different species of morass **(Jain *et al*., 1990; Sharma *et al*., 1990; Yadav *et al*., 1990; Patnaik and Chand, 1997; Chitra and Padmaja, 2002).** Biotechnological applications have great promise in further improving the mulberry crop, conventional research has not been as successful as hoped. Biotechnological research in genome characterization with isozymes and DNA markers, micro-propagation, *in vitro* preservation technologies such as reproduction from callus, somatic hybridization, slow storage and cryopreservation, and genetic mutations **(Dandin and Naik, 2004).** Native genotypes found under similar agro-climatic conditions provide an advantage that can be used much easier for breeding purposes than in remote areas. Therefore, valuable genetic resources of existing indigenous genotypes must be preserved for their proper use. To obtain this, it is essential to assess the genetic variation between native genotypes. **(Vijayan *et al*., 2006).** Studies on the mulberry gene were first started in Japan (**Katagiri *et al*., 1984),** where chloroplast DNA successfully isolated from mulberry. Various molecular symbols, such as direct amplification of mini-satellite DNA (DAMD) **(Fotadar *et al*., 1990)**. Randomly Amplified Polymorphic DNA (RAPD) **(Chatterjee *et al*., 2004)**, Inter Simple Sequence Repeats (ISSRs) **(Vijayan *et al*., 2006)**, and Amplified Fragment Length Polymorphism (AFLP) **(Sharma *et al*., 2000)** used to study the genetic variation of mulberry varieties. Improving yield and fruit quality through breeding relationships between genetic variants and selected mulberry genotypes (*Moras* sp.) have been evaluated. The main objectives of our study are developing an improved protocol for large scale production *in vitro* multiplication system of black mulberry (*Morus nigra* L.) as a first step for mulberry germplasm conservation, and genetically characterization of some mulberry (*Morus sp*.) genotypes which growing in Taif province, KSA using DNA based markers.

Comment [i-[3]: 1. There is a focus on information on how many types of Moris Sp. was found in the study sites in Saudi Arabia.

2. Reinforce other supporting phenomena why choose black mulberry (Morus nigra L.) among ot types. That fact can be from the taste that many people prefer, the ease of cultivation and production, or other aspects.

2.Materials and Methods

2.1. Plant Materials: Nodal explants (including black mulberry (*Moras nigra* L.) auxiliary buds and shoot tips collected from juvenile branches) are varieties of trees grown in El Shafa regions (21°05'04.2"N 40°21'45.6"E) in Taif Governorate, Saudi Arabia.

2.2.Micro-propagation: 1-2 cm long pieces of explants have been surface-sterilized and placed vertically in MS medium is associated with different concentrations and combinations of auxin and cytokinin. MS media without growth regulators is used as a control treatment for all experiments.

2.2.1.Shoot Initiation Stage: Axillary buds and shoot tips were cultured in MS medium supplemented with vitamins for four weeks.

2.2.2. Shoot Multiplication and Elongation Stages: For shoot multiplication and elongation, induced subcultures were displayed in full strength MS medium for another 4 weeks with combinations of different cytokinins concentrations.

2.2.3. Rooting and Acclimatization Stages: The elongated branches (3 to 4 cm long) were transferred to half-MS medium to grow to different densities and roots and replaced with auxin compounds for 4 weeks. Then, the rooted plants are planted in clean peat moss plastic pots for adaptation.

2.3.1. DNA Isolation: The whole genetic DNA was isolated from the leaf tissue using the CTAB method with some modifications **(Doyle and Doyle, 1990)**.

2.3.2. Inter - Simple Sequence Repeats (ISSRs) Analysis: For ISSR-PCR analysis, a total of ten primers were used to select the best amplification results with DNA samples.

The amplification products were separated by electrophoresis on 1.5% agarose gel mixed with ethidium bromide and the bands were visualized and documented in a UV gel doc. System.

2.4. Data Analysis for ISSR: DNA polymorphisms of the ISSR were analyzed. Only stable and clear bands in replicas are considered potential polymorphic markers. Data obtained by scoring the presence (1) or absence (0) of amplified fragments from ISSR analysis. The similarity coefficient (F) and dendrogram formula were reported using the unpaired pair method and the arithmetic mean (UPGMA) **(Rohlf, 1990).**

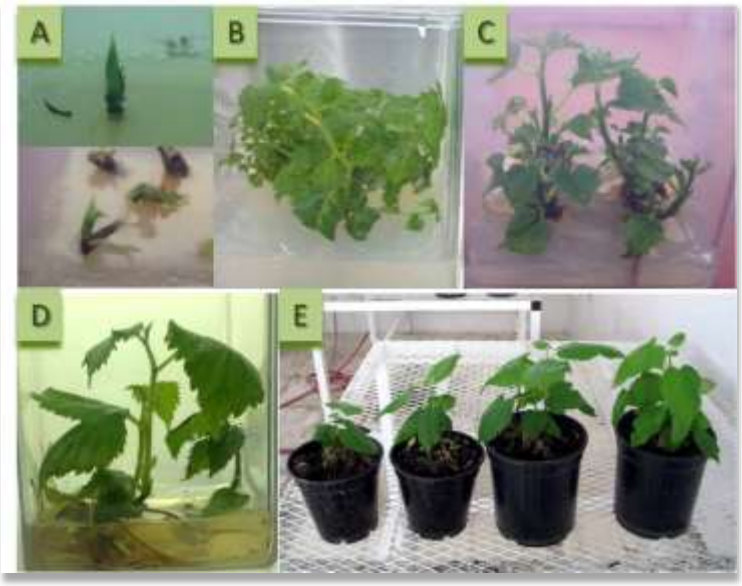
2.5. Statistical Analysis: A completely random design was used for the *in vitro* campaign of all experiments. Analysis and comparison of differences between treatment mean values for the *in vitro* diffusion experiment was performed using the Duncan test at a 5% probability (0.01 = <p <0.05) level using the Statistical Support Software (ASISSAT) version 7.6 beta vas. (2014).

3. Results and Discussion

Two to three axillary buds' nodal segments and epical buds from juvenile branches of *Moras nigra* L. have been grown in MS medium containing the most effective concentrations of BA (0.5 and 2.0 mg / L) and 2 i.p. (0.5 and 1.0 mg / L) (Table 1).

Associated with 1 mg / L IP and 2 mg / L BA in 2 MS basal media. The shoot buds sprouted in a maximum rate in the cultures after two passages of inoculation, the current research of *M. nigra* demonstrates the possibility of large-scale mulberry promotion through nodal and shoot tip cultures. Auxiliary buds or shoot tip cultures are preferred according to ease of meristem development to shoots while maintenance of clonal fidelity. Light to moderate nodal transplant of medium thickness (0.5 - 0.6 cm) responds more favorably to bud germination and differentiation with emerging green axillary buds. 35-80% of nodules and 20-70% of shoot tip details on MS associated with various plant growth regulators have a seedling survival percentage and their subsequent development (Table 1).

Figure- 1. Mulberry (M. nigra) micro-propagation stages (A: Shoot initiation, B: multiplication, C: elongation, D: rooting and E: acclimatization stage in greenhouse of four months old plantlets).



Two weeks after vaccination the shoot buds spread to several shoots in the same medium. These sprouts were transferred to a new medium of the same composition and maintained for four weeks. When vaccinated against MS basal medium fortified with BA (2.0 mg / l) in combination with (1.0 mg / l) 2 i.p., these descriptions showed the appearance of shoot buds in cultures six days after vaccination showed maximum response.

Table- 1. Effect of different concentrations and combinations of two cytokinin's (2 ip & BA) on shoot differentiation, multiplication, and average shoot length of (*Morus nigra*).

Cytokinins conc. (mg/l)		Number of Explants /treatments	Mean of No. Explants differentiation	Mean of No. of multiple shoot	Mean of Average shoot length (cm)
2ip	**BA**				
0.0	**0.0**	60	00^{i}±00	00±000	00^{e}±00
	0.5	60	13^{f}±1.55	1.0^{g}±1.00	1.0^{d}±1.32
	1.0	60	17^{e}±1.62	1.3^{f}±1.11	1.3^{d}±1.38
0.5	**1.5**	60	22^{d}±1.70	2.6^{e}±1.17	1.6^{cd}±1.42
	2.0	60	37^{c}±1.74	9.0^{b}±1.47	2.0^{cd}±1.42
	0.5	60	23^{d}±1.78	3.0^{d}±1.29	2.0^{cd}±1.45
	1.0	60	36^{c}±1.80	5.0^{c}±1.41	3.0^{bc}±1.47
1.0	**1.5**	60	41^{b}±1.82	8.0^{b}±1.53	4.0^{ab}±1.48
	2.0	**60**	**55^{a}±1.83**	**13^{a}±2.33**	**5.0^{a}±1.49**

Means with the same letter are not significantly different according to Duncan Test at a level of 5% of probability (.01=<p<.05).

Similar results were obtained by **(Zafar *et al*., 2013)** From the nodal researchers of *Moras levigata*. The production of shoots from nodal sections was also established **(Kang *et al*., 2006)**. But they achieved shoe multiplication by growing plants in a fortified MS medium with glutamine (1 mg / l) as well as BA (2.5 mg / l). This medium facilitated the germination of nodal segments from shoots elongated and increased micro-cuttings *in vitro*.

These buds generated into several shoots after 2 weeks of inoculation. Lobed and un-lobed leaves like naturally mother plants were produced from micro shoots. After 15 days of inoculation, the shoots had been established grown with light green color. Explants were cultured on basal MS medium supplemented with BA (0.5-1.0 mg/l) + NAA (1.0- 2.0 mg/l) to develop complete plantlets. After 6-8 days of inoculation, explants appeared 70-80% of morphogenetic potential for shoot and root differentiation. After four weeks, enhanced growth along with the production of roots. In media containing BAP + 2IP in combination with 0.5 / 0.5 mg / l, the frequency of shoot buds was lower and a slight calling from the lower cut edge of the specification was also observed (Fig. 1). Consistent with these results, Kn is less effective than BAP for both shoot tip and nodal exfoliation shoot induction for three different types of mulberries, these results agreed with **(Yadav *et al*., 1990; Patnaik and Chand, 1997; Chitra and Padmaja, 2005).**

Table- 2. Effect of different concentrations and combinations of two auxins (IBA & NAA) on Rooting differentiation, number of roots/ explant and length of roots of Mulberry (Morus nigra L.).

Auxin conc. (mg/ l)		No. shoot tips/treatment	Mean of No. of Rooting differentiation	Mean of Rooting %	Mean of No. of roots/ explant	Mean of length of roots (cm)
IBA	**NAA**					
00	**00**	30	$00^{e}\pm000$	$00^{e}\pm000$	$00^{d}\pm000$	$00^{e}\pm000$
0.5		30	$2.1\pm^{1.22}$	$17^{d}\pm7.60$	$1.6^{c}\pm1.34$	$1.7^{d}\pm0.55$
1.0		30	$3.9^{d}\pm^{1.87}$	$24^{d}\pm8.08$	$1.8^{c}\pm1.51$	$3.0^{bc}\pm0.61$
1.5	**0.5**	30	$9.0\pm^{2.33}$	$33^{c}\pm8.27$	$3.0^{b}\pm1.69$	$3.9^{c}\pm0.68$
2.0		30	$15^{b}\pm^{2.78}$	$87^{b}\pm8.65$	$5.0^{b}\pm1.87$	$4.7^{ab}\pm0.70$
2.5		**30**	$\mathbf{19^{a}\pm^{3.11}}$	$\mathbf{98^{a}\pm8.9}$	$\mathbf{8.0^{a}\pm1.99}$	$\mathbf{5.8^{a}\pm0.77}$

Means with the same letter are not significantly different according to Duncan Test at a level of 5% of probability (.01=<p<.05).

The long multiple branches (2 - 3 cm) have been cut and transferred to rooting media (Table 2). MS medium supplemented with 0.5 mg/l NAA in combination with 2.5 mg/l IBA was optimal for root development for 3 weeks (Fig. 1). NAA was an effective rooting agent for *M. alba* as reported by **(Anuradha and Pullaiah, 1999).**

In small plastic pots, the well-developed shoot-roots plantlets with 90% survival rate (Fig. 1) transferred to a mixture of sand: soil: organic manure (2: 2: 1). The technique described here provides a good method for the rapid propagation of this crop on a commercial scale as well as for the inclusion of bouquets from economically important plant species and cultured auxiliary buds.

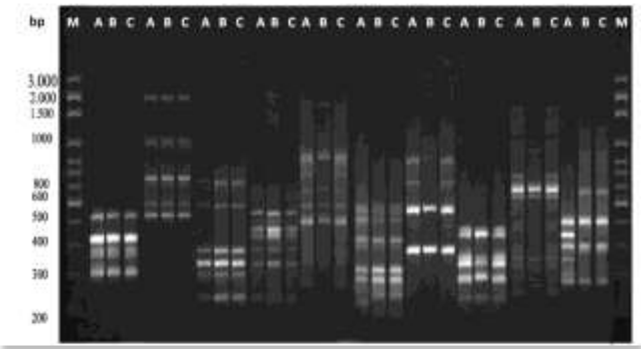
Mulberry Genetic Diversity

Various molecular markers have very important role in plant breeding programs and genetic conservation through detection of genetic distances of genotypes or plant germplasms **(Koohi *et al*., 2007)**. From these molecular markers, RAPD **(Williams *et al*., 1990; Nagaoka and Ogihara, 1997)** and ISSR **(Zietkiewiez *et al*., 1994; Tsumara *et al*., 1996; Nagaoka and Ogihara, 1997; Souza and Martins, 2004; Venkatachalam *et al*., 2007; Joshi and Dhawan, 2007; Chandrika *et al*., 2008; Chandrika *et al*., 2010)** are popular tools for identification of differences between plant accessions. In our study, ISSR technique used to identify genetic variation in 30 plant specimens of three mulberry genotypes two (*M. alba* and *M. nigra*) from common cultivated in Taif region in KSA, and one wild growing (*M. nigra*). Fifteen primers produced bright amplification products and polymorphisms from 22 previously demonstrated ISSR primers and were selected for further analysis. A total of 138 reliable fragments were obtained (Figure 2). Of these, 126 bands are polymorphic (91.3%), giving a score of more than 9.2 per primer.

Average number of allele variants observed in one locus (1.93). Of the mulberry varieties, 15 ISSR primers produced 104 bands, of which 84 bands (80.7%) were polymorphic. Similarly, among wild species, 15 ISSR primers spread over 104 bands, of which 87 (83.7%) were polymorphic, indicating that wild species contained more polymorphisms than cultivated species. Here is the PIC value of each ISSR primer averaging (0.0966 to 0.3049) (0.2006). Among the 126 polymorphic bands, we found some specific bands that are used for mulberry mixing and differentiation. 29 fragments, 23.01% polymorphic fragments, putative accessibility-specific markers (data not shown). Considered exclusively for fourteen species (data not shown).

Comment [i-[4]: What are the consequences wild species? So what are the effects on cultivate species?.

Figure- 2. DNA polymorphisms amplified from the DNA extracts of three mulberry genotypes [M. alba (A), cultivated M. nigra (B) and wild M. nigra (C)] using ten ISSR primers. M = DNA marker (100 bp DNA ladder).



246 fragments ranging from 6–12 bands per primer for each cultivar have been produced from ten ISSR primers (Table 3). The size of the expanded products ranged from 314.33 to 2299.9 bp and the percentage of total polymorphic markers and polymorphisms was 18 and 6.7%, respectively. Primer CGC(GATA)4 amplified maximum number of polymorphic unique bands (3). The PIC values, the reflection image of the allelomorphic variation, and the frequency between types, are not the same for all ISSR locations tested. The minimum similarity between the two native genotypes *M. alba* and wild-growing *M. nigra* (70.2) and the maximum similarity to *M. nigra* (89) and the result of the wild-growing *M. nigra* cultivated in the genotype were shown. The average similarity index is 87.9.

Data obtained from ISSR analysis is subject to UPGMA analysis. The co-phenetic correlation coefficient (87.9) shows a slight distortion between the actual similarity values from the matrix and the values used to construct the dendrogram. Cluster analysis was performed based on a consistent matrix of jacquard similarity calculated from ISSR markers. With 91% similarity, the two genotypes were classified as One group, the rest of the cultivators were put into separate groups.

Table- 3. Unique bands for each Mulberry cultivar with each ISSR primer.

No.	ISSR primer	Sequence	*M. alba*		*M. nigra* (cultivated)		*M. nigra* (wild grown)		*TUPMs for all cvs.
			+ m	-m	+ m	-m	+ m	-m	
1	ISSR- 03	5'- ACACACACACACACACY T-**3'**	1	0	0	0	0	0	**1**
2	ISSR- 05	**5'-** GTGTGTGTGTGTGTGTYG **-3'**	0	0	0	0	0	-1	**0**
3	ISSR- 06	**5'-** CGCGATAGATAGATAGA T **-3'**	1	1-	0	0	0	-2	**1**
4	ISSR- 09	**5'-** GATAGATAGATAGATAG C **-3'**	-1	0	0	0	0	0	**0**
5	ISSR- 10	**5'-** GACAGACAGACAGACAA T **-3'**	1	-1	0	0	0	0	**1**
6	ISSR- 11	**5'-** ACACACACACACACACY A **-3'**	0	0	2	0	2	0	**4**
7	ISSR- 12	**5'-** ACACACACACACACACY C **-3'**	0	0	0	0	1	0	**1**
8	ISSR- 15	**5'-** CTCTCTCTCTCTCTCTRG **-3'**	1	0	0	0	0	-1	**1**
9	ISSR- 16	**5'-** TCTCTCTCTCTCTCTCA **-3'**	0	0	0	0	1	0	**0**
10	ISSR- 19	**5'-** HVHTCCTCCTCCTCCTCC **-3'**	0	0	0	0	0	0	**0**

*(TUPMs) Total unique positive markers.

Furthermore, the four distinct bands produced by primers (GATA) 4GC at 530 bp, (GT) 8YG at 1910 bp, (GAG) 4GC 2500 bp and 990 bp were clearly distinguished between mulberry cultivars and wild species are separated (Table 3). The similarity coefficient ranged from 0.6014 to 0.9493 with an average of

0.7677, revealing a high level of genetic variation in the mulberry entries studied and it was possible to discriminate among all the mulberry entries analysed. The highest genetic similarity coefficient (0.9284) was found between cultivated *M. nigra* and wild *M. nigra*, indicating that they had almost identical genetic components. The lowest genetic similarity coefficient (0.5113) was found between *M. alba* and wild *M. nigra*, indicating that they are relatively far apart.

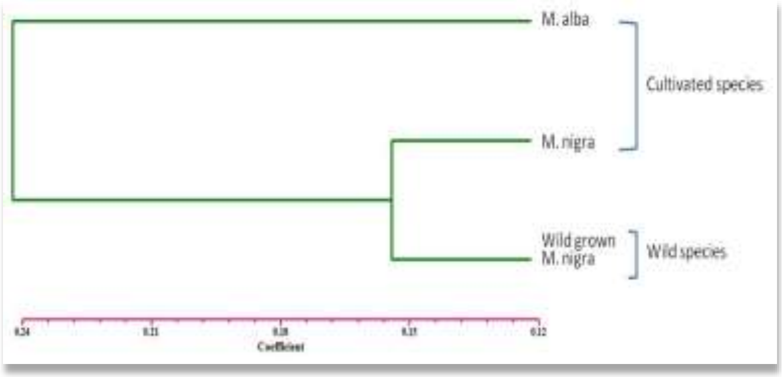


Figure- 3. A dendrogram obtained by UPGMA for 3 mulberry genotypes based on ISSR markers.

3. Conclusion

The ISSR profile was used to determine the genetic similarity standard, which was used to construct the dendrogram by the UPGMA method. The first and second major coordinates accounted for 52.5% and 10.0% of the total variation, respectively. Among the cultivars cultivated in the first group, *M. alba* belongs to the genus *Macromorse* in the morphological classification of the genus *Morus* and differs independently from other mulberry species, cultivated *M. nigra* and wild *M. nigra* are grouped together. Close correlation with 0.9348 genetic similarity coefficient. Dendrograms obtained with ISSR markers (Figure 3) show similar topology with ISSR markers from other authors, although there are some differences in the placement of some genotypes. From PCA analysis, as in other marker methods, cultured mulberry genotypes are not fully integrated, possibly since different molecular markers are formed due to differences.

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Influence of Yara fertilizer formulations on rice productivity in the Guinea savanna zone of Ghana

Abstract

Low soil fertility has been a major constraint to the increased and sustainable rice production in the Guinea savanna zone of Ghana. Studies were conducted in four locations to evaluate the yield of rice under different Yara fertilization regimes. The fields were laid out in a randomized complete block design with four replications for each treatment. Data were collected on grain yield and seed mass, and subjected to analysis of variance, with treatment means separated at 5% level of significance. Significant improvement in rice paddy yield was realized in all study locations due to the fertilizer treatments. Grain yield improvement of up to 4,280 kg/ha was realized. The best two performing treatments in improving rice grain yield were UNIK-L+AMI-L and ACT-L+AMI-L and ACT-L+URE-L, in descending order. At most locations, rice grain yield among the CropLiftBio foliar treatments was statistically similar. Application of ACT+URE and UNIK+ACT without CropLiftBio foliar supplementation consistently demonstrated lower rice grain yields compared to the other fertilizer treatments in all study locations. Rice grain mass was however, not significantly impacted by the fertilizer treatments at any of the study locations. From the results of this study, Actyva fertilizers used as basal appeared to be unsuitable for rice production in the savanna ecology of Ghana as these generally provided lower grain yields. For maximum grain yield of rice in the ecology, Yara UNIK 15 (NPK 15:15:15) fertilizer was the most recommended. The basal application of UNIK 15 at 125 kg/ha and topdressing with Amidas at 125 kg/ha with CropLiftBio foliar supplementation will provide better yields for farmers than applying Actyva as topdress.

Comment [i-[1]: Consistency of writing unit weight of grain production: ton/ha.

Comment [i-[2]: What is this described in the next section? Among other things, the content of nutrients.

Keywords: Yara fertilizer; Grain yield; Oryza sativa; Ghana; Savanna ecology.

1.0 INTRODUCTION

Rice is among the most important and widely consumed staple food in tropical Africa (FAO, 2020). In the savanna ecology of Ghana, rice is produced predominantly by smallholder, resource-poor farmers under rain-fed conditions (Kankam-Boadu et al., 2018). Sun et al. (2019)

reported that rice is most popular cereal crop in northern Ghana due to its high yield and low cost of production. However, the average yield of about 1.5 t/ha is below the achievable yields of up to 6 t/ha (Oppong-Abebrese et al., 2019. Soil fertility is crucial in increasing cereal crop yields, and low soil fertility and low application of external inputs are the major factors affecting productivity of rice, and these account for the low yield of the crop. Improving yields through increased productivity of the savanna soils can be achieved by external inputs of nutrients which are available mainly in the form of inorganic fertilizers.

Across the north of Ghana, the most sourced of inorganic fertilizers are commercial fertilizers, which farmers can easily access on the local market. The main limiting nutrients in the soils of the major maize growing areas in northern Ghana have been organic carbon (< 0.2 %), exchangeable potassium (< 10 mg/kg) (Abumere et al., 2019). For many decades, a one-cap-fits-all fertilizer recommendations have been made for rice and other crops in Ghana. Moreover, soil conditions are dynamic over the years and the old recommendations are not always efficient (e.g. Darma et al., 2020). Hence, the need to constantly update or make site-specific fertilizer recommendations for rice in the northern agroecological zone of Ghana.

Comment [i-[3]: It's more appropriate to plant rice, not corn.

Over the years, use of NPK fertilizers have been the primary means of nutrient replenishment. This is understandable as NPK remains the most important nutrients required for crop production (Abumere et al., 2019). Sole application of NPK has helped to increase rice yield significantly. However, some room remains for further yield increment. It has been postulated that the inclusion of secondary nutrients such as sulphur (S) and micro nutrients such as boron (B) and Zinc (Zn) in fertilizer blends could increase rice yields sharply, beyond levels achieved by use of sole NPK (Njoroge et al., 2018). This postulate has not been confirmed nor denied in savanna ecology of Ghana. In view of this, fertilizer blends/formulation in northern Ghana remains primarily of N, P and K which may be limiting possible yield increment through secondary and micro-nutrient inclusion. There is the need to study the growth and yield increment of fertilization through inclusion of secondary and micronutrient elements in fertilizer formulations.

YARA Ghana Limited is an agro input company involved in the importation and sale of mineral fertilizers to improve agricultural production and income of farmers. Yara Ghana has recently introduced standard fertilizer formulations for cereal crop production, namely YaraMila Actyva (23N+10P+5K+2MgO+3S+0.3Zn), Unik-15 (15N+15P+15K+2.2S), YaraVita Croplift Bio

(8.5N+3.4P+6K+B+Cu+Mn+Mo+Zn), YaraVera Amidas (40N+5.6S) and YaraBela Sulfan (24N+6S). The comparative agronomic efficacy of these formulations within the different agro ecological zones in northern Ghana remains largely unknown. There is the need to compare the relative productivity of the fertilizer regimes to enable subsequent recommendation to the resource poor farmer for rice production in the ecology. This study sought to establish and compare the yields of rice obtained from treatments with the various YARA fertilizer formulations within the different agroecological zones of northern Ghana.

2.0 MATERIALS AND METHODS

2.1 Study sites

Comment [i-[4]: It is better to complement the chemical properties of the soil: pH, CEC, N-total, P available and total, K available and total, etc. Not only ecological traits.

The trial was conducted during the 2021 cropping season in farmers' farms in four locations, namely, Nyankpala, Walewale, Yendi and Damongo, in the northern Guinea savanna zone of Ghana. Generally, the savanna ecology is that of a tropical continental with a single rainy season, usually from May to October (and peaks around late August or early September), followed by an extended dry season (FAO, 2020; Tetteh et al., 2016).

The four locations for this study share ecological traits similar to the Guinea savanna ecological zone. However, there are some differences. Nyankpala is at an altitude of about 183 m above sea level and mean annual rainfall of about 1000 – 1300 mm. The area has a gentle undulating to flat terrain (Kumah, 2016). The area is largely characterized by low-lying areas of grassland with few spread perennial woody species. Some crops cultivated in this ecology include maize, rice, soybean and cowpea. Soils in this region are largely developed from voltaian shale and sandstone with texture being largely sandy loam to loamy sand (Yidana et al., 2011) and classified as a Ferric Luvisol. Yendi largely shares similar ecological traits with guinea savanna. On the other hand, unique traits include average annual rainfall which ranges between 1005 – 1150 mm. The area has a relatively flat terrain with gentle slopes. Soils here are developed over shale, usually shallow (15-30 cm) to very shallow (cultivated include maize, millet, rice, groundnuts, beans, sorghum and yam.

2.2 Land preparation, experimental design and treatments

At each location, stumps were initially removed from the fields to ease demarcation. Each field was disc-ploughed and harrowed (with a hoe) during the first week of July.

Comment [i-[5]: Please consider adding references: e.g. Darma et al. (2022).

2.3 Trial Protocols

The main purpose of the study was to evaluate the effect of the different YARA fertilizer formulations and application rates on the agronomic performance of rice across the four agroecological zones. The different fertilizer protocols evaluated for the crop are presented in Table 1 below:

Table 1: Protocols for rice trial, 2021 season

Treatments	2 WAP	Beginning of tillering	At panicle initiation
ACT-L+AMI-L	YaraMila Actyva @250kg/ha	CropLift Bio@ 2l/ha	YaraVera Amidas@125kg/ha
ACT-L+URE-L	YaraMila Actyva @250kg/ha	CropLift Bio@ 2l/ha	Urea@125kg/ha
UNIK-L+ACT-L	UNIK 15:15:15@250kg/ha	CropLift Bio@ 2l/ha	YaraMila Actyva @125kg/ha
UNIK-L+AMI-L	UNIK 15:15:15@250kg/ha	CropLift Bio@ 2l/ha	YaraVera Amidas@125kg/ha
UNIK-L+URE-L	UNIK 15:15:15@250kg/ha	CropLift Bio@ 2l/ha	Urea@125kg/ha
ACT+AMI	YaraMila Actyva @250kg/ha	No fertilizer	YaraVera Amidas@125kg/ha
ACT+URE	YaraMila Actyva @250kg/ha	No fertilizer	Urea@125kg/ha
UNIK+ACT	UNIK 15:15:15@250kg/ha	No fertilizer	YaraMila Actyva @125kg/ha
UNIK+AMI	UNIK 15:15:15@250kg/ha	No fertilizer	YaraVera Amidas@125kg/ha
UNIK+URE	UNIK 15:15:15@250kg/ha	No fertilizer	Urea@125kg/ha
CONTROL	No fertilizer	No fertilizer	No fertilizer

2.4 Trial locations

The trials were conducted on-farm in four localities, namely Walewale, Yendi, Damongo and Nyankpala, representing the various agro-ecological zones in the north of Ghana. At each location, a total of three sites were selected for the trials on the three different crops. The site selection was based on the extent of cultivation of the target crops; the more extensive the cultivation of a given crop the higher the probability of inclusion in siting of the trials. Agricultural Extension Agents (AEAs) from the Ministry of Food and Agriculture (MoFA) operating within each zone were initially engaged to assist with the selection of farmers. The choice of fields selected depended on accessibility and proximity to the major road and willingness of the land owner to participate in the trial.

2.5 Land preparation and field layout

At all locations, each field was ploughed with a tractor and later manually leveled with a hoe. Stumps were initially removed from fields by the farmers to ease demarcation and ploughing. The dates of land preparation and field layout for the three crops in the various locations are shown in Table 5 below.

For each site, the fields were demarcated as a single factor experiment laid out in a Randomized Complete Block Design with three replicates for each treatment. Field sizes of 29 m x 19 m and plot sizes of 5 m x 4 m were covered. A 1 m and 2 m alleys were left between treatments in each block and between blocks, respectively.

2.6 Planting and application of fertilizer treatments

The AGRA rice variety used for planting at all sites. Planting was done between the first and third weeks of July, 2021. Planting was done at four seeds per hill and later thinned to the appropriate plant stands of 3 seedlings per hill after germination.

The broad-spectrum pre-emergence herbicide, Glyphader 480, was used to control the weeds in each field at planting. The basal fertilizer treatments were applied from two weeks after planting as indicated in the protocol.

2.7 Data collection and analysis

Sampling for yield data was done after manual harvest of the crops. The crop was harvested using sickle. Harvesting was done on plot bases. After harvesting, rice paddy were manually threshed on plot bases, and winnowed. Harvesting of plots were done separately in accordance with each treatment. Threshed grains were air dried to ~13% moisture content by weight. The weighed grains per plot were converted into weight per unit area (kg/ha).

Comment [i-[6]: Writing consistency of ton/ha.

The weight of 1000 grains of paddy were taken to investigate the effect of the nutrient regimes on grain mass.

All the yield data were analyzed using analysis of variance (ANOVA) in GenStat Statistical package 12th edition. The treatment means were separated and compared using the Least Significant Difference (LSD) at 5% level of probability.

3.0 RESULTS

3.1 Rice paddy yield

Rice paddy yield at Nyankpala was significantly affected (P<0.001) by the fertilization regimes (Table 2). Rice paddy yield ranged from 433 kg/ha in the unfertilized (control) plot to 4280 kg/ha in ACT-L+ACT-L. Yield among the fertilizer treatments without CropLiftBio application was not statistically different. Rice plants that received CropLiftBio foliar application gave significantly better yields than those without the foliar fertilizer. Among the foliar treatments, rice grain yield was statistically similar. Average yield increases over the control was 411% in ACT+URE and 888% and 152% in ACT-L+AMI-L.

Comment [i-[7]: The importance of the description of CropLiftBio so that it affects rice yields.

Rice paddy yield at Walewale was significantly affected (P<0.001) by the fertilization regimes. Grain yield ranged from 320 kg/ha in the unfertilized (control) plot to 4240 kg/ha in UNIK-L+AMI-L plot. All rice plots that received fertilization had significantly higher yields than that of the control (Table 3). Rice grain yield among the ACT+URE, UNIK+AMI, UNIK+URE, ACT+AMI and NPK+ACT treatments did not differ significantly. Grain yield among the CropLiftBio treatments were significantly higher than those with no CropLiftBio. Among the CropLiftBio treatments, ACT-L+AMI-L or NPK-L+AMI-L had the highest yield.

Rice grain yield at Damongo was significantly affected (P<0.001) by the fertilization regimes. Grain yield ranged from 440 kg/ha in the unfertilized (control) plot to 2440 kg/ha in ACT-L+AMI-L plot (Table 4). With the exception of ACT-L+URE-L, UNIK-L+AMI-L and ACT-L+AMI-L which had significantly higher yield, grain yield from the other fertilizer treatments was statistically similar. There was yield increment of at least 142% over the control.

Rice paddy yield at Yendi was significantly affected (P<0.001) by the fertilization regimes (Table 5). Grain yield ranged from 3787 kg/ha in UNIK-L+AMI-L to 1467 kg/ha in the unfertilized (control) plot. With the exception of UNIK+URE, all the rice plots that received fertilization had significantly higher yields than that of the control. Grain yield obtained from ACT-L+URE-L or ACT-L+AMI-L was similar to those from the other fertilizer treatments with no CropLiftBio. Average yield increases of 39% and 158% over the control were recorded from the UNIK+URE and UNIK-L+AMI-L treatments, respectively.

Table 2: Effect of YARA fertilization regimes on rice grain yield at Nyankpala, 2021 cropping season.

Comment [i-[8]: Provide a column for the Table.

Fertilization regimes	Grain yield (kg/ha)
CONTROL	433 a
ACT+URE	2213 b
UNIK+AMI	2213 b
ACT+AMI	2360 b
UNIK+URE	2387 b
UNIK+ACT	2680 b
UNIK-L+URE-L	3673 c
UNIK-L+ACT-L	3787 c
ACT-L+URE-L	4027 c
UNIK-L+AMI-L	4107 c
ACT-l+AMI-L	4280 c

LSD (0.05) = 657.5; P<0.001

~~Figure~~ Tabel **3:** Effect of YARA fertilization regimes on rice grain yield at Walewale, 2021 cropping season.

Comment [i-[9]: Provide a column for the Table. It's not a "Image", but rather a "Table".

Fertilization regimes	Grain yield (kg/ha)
CONTROL	320 a
ACT+URE	2120 b
UNIK+AMI	2240 b

UNIK+URE	2320 b
ACT+AMI	2573 b
UNIK+ACT	2627 b
UNIK-L+ACT-L	3440 c
ACT-L+URE-L	3507 c
UNIK-L+URE-L	3560 c
ACT-l+AMI-L	3867 cd
UNIK-L+AMI-L	4240 d

LSD (0.05) = 539.6; P<0.001

Table 4: Effect of YARA fertilization regimes on rice grain yield at Damongo, 2020 cropping season.

Comment [i-[10]]: Provide a column for the Table.

Fertilization regimes	Grain yield (kg/ha)
CONTROL	440 a
ACT+URE	1067 ab
UNIK+ACT	1173 b
UNIK+AMI	1200 b
ACT+AMI	1600 bc
UNIK+URE	1707 bcd
UNIK-L+ACT-L	1747 bcd
UNIK-L+URE-L	1813 bcd
ACT-L+URE-L	2027 cd
UNIK-L+AMI-L	2147 cd
ACT-L+AMI-L	2440 d

LSD (0.05) = 695.1; P<0.001

Table 5: Effect of YARA fertilization regimes on rice grain yield at Yendi, 2021 cropping season.

Comment [i-[11]]: Provide a column for the Table.

Fertilization regimes	Grain yield (kg/ha)
CONTROL	1467 a
UNIK+URE	2040 ab
UNIK+ACT	2640 bc

UNIK+AMI	2693 bc
ACT-L+URE-L	2880 bcd
ACT-l+AMI-L	2933 bcd
ACT+URE	2960 bcd
ACT+AMI	3027 cd
UNIK-L+ACT-L	3667 d
UNIK-L+URE-L	3733 d
UNIK-L+AMI-L	3787 d

LSD (0.05) = 860.6; P<0.001

3.2 Rice grain weight

The results on seed weight however showed that the fertilization regimes had no significant effect on rice 1000 seed weight at Nyankpala (P=0.14) (Table 6), even though the highest seed weight (25.50 g) was recorded from UNIK-L+AMI-L while the lowest (24.63 g) was recorded from the control (Table 6).

The fertilization regimes had no significant effect on rice 1000 seed weight at Walewale (P=0.95). The highest seed weight (27.53 g) was recorded from UNIK+URE while the lowest (26.80 g) was recorded from ACT-L+AMI-L (Table 7).

The fertilization regimes had no significant effect on rice 1000 seed weight at Damongo (P=0.44). The highest seed weight (27.53 g) was recorded from NPK+URE while the lowest (26.80 g) was recorded from ACT-L+AMI-L (Table 8).

Rice 1000 seed weight was not significantly affected by the fertilization regimes at Yendi (P<0.43), even though the highest seed weight (26.97 g) was recorded from UNIK+URE while the lowest (26.13 g) was recorded from the control (Table 9).

Table 6: Effect of YARA fertilization regimes on rice 1000 grain weight at Nyankpala, 2021 cropping season.

Comment [i-[12]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
ACT-L+URE-L	24.63 a
UNIK-L+URE-L	24.67 a

UNIK+AMI	24.73 a
ACT+AMI	24.80 a
ACT+URE	25.30 a
UNIK-L+ACT-L	25.33 a
CONTROL	25.37 a
UNIK+ACT	25.40 a
ACT-l+AMI-L	25.50 a
UNIK+URE	25.50 a
UNIK-L+AMI-L	25.50 a

LSD (0.05) = 0.82; P=0.14

Table 7: Effect of YARA fertilization regimes on rice 1000 grain weight at Walewale, 2021 cropping season.

Comment [i-[13]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
ACT-L+AMI-L	26.80 a
ACT+AMI	27.13 a
UNIK-L+ACT-L	27.13 a
UNIK+ACT	27.20 a
UNIK-L+URE-L	27.30 a
CONTROL	27.33 a
ACT-L+URE-L	27.37 a
UNIK-L+AMI-L	27.37 a
UNIK+AMI	27.40 a
ACT+URE	27.47 a
UNIK+URE	27.53 a

LSD (0.05) = 1.01; P=0.95

Table 8: Effect of YARA fertilization regimes on rice 1000 grain weight at Damongo, 2021 cropping season.

Comment [i-[14]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
UNIK+AMI	26.13 a
ACT-l+AMI-L	26.37 a

ACT+AMI	26.47 a
ACT-L+URE-L	26.53 a
UNIK-L+AMI-L	26.57 a
UNIK+ACT	26.73 a
UNIK-L+URE-L	26.90 a
UNIK-L+ACT-L	26.93 a
CONTROL	26.97 a
UNIK+URE	26.97 a
ACT+URE	27.10 a

LSD (0.05) = 0.87; P=0.44

Table 9: Effect of YARA fertilization regimes on rice 1000 grain weight at Yendi, 2021 cropping season.

Comment [i-[15]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
ACT-L+URE-L	26.13 a
UNIK+AMI	26.47 a
ACT+AMI	26.47 a
UNIK-L+AMI-L	26.57 a
UNIK-L+URE-L	26.57 a
ACT-l+AMI-L	26.70 a
CONTROL	26.73 a
UNIK+ACT	26.73 a
ACT+URE	26.87 a
UNIK-L+ACT-L	26.93 a
UNIK+URE	26.97 a

LSD (0.05) = 0.79; P=0.61

4.0 DISCUSSION

Results from this study have demonstrated that availability of adequate nutrients could improve growth and yield parameters of rice in the study locations. The higher paddy yield obtained from UNIK-L+AMI-L treatment could be due to the action of NPK, Urea and Sulphur in that fertilizer regime. This NPK product (also called T15 or UNIK 15), is composed of NPK 15-15-15 fertilizer, and every granule of T15 contains total N, P, K nutrition. Yara T15 products include a balance of nitrate and ammonium nitrogen, making the products significantly more effective than urea of ammonium-based fertilizers per unit of nitrogen. This formulation is known to dissolve quickly and evenly when in contact with the soil in humid conditions or after a night's dew. In dry climates, the higher solubility of the products helps nutrients reach the roots where limited soil moisture is available. In tropical climates nutrients move rapidly into the soil, avoiding potential for soil surface run-off due to heavy rain, and thus, promoting rice growth and productivity.

Also, T15's nitrophosphate production process gives the formulation a unique combination of polyphosphates and orthophosphates. These forms give greater availability of soluble phosphate to the rice plant over a wide range of soil types. oreover, Amidas is made up of 40 N + 5.6 S. This is an improved Urea with Suphur fertilizer Yara Amidas is a unique granular fertilizer that is 100% soluble and very efficient. The product contains nitrogen and sulphate sulphur that is totally available to the rice crops in an ideal N:S ratio of 7:1. The nitrogen is mostly available in the urea form, making it ideal for rice growth, yield and productivity especially in the relatively poor soils of northern Ghana. Furthermore, the sulphur content of Amidas improves nitrogen efficiency from urea by reducing nitrogen volatilisation losses by up to 35% on low pH soils; a property that is generally lacking in our conventional physical blends of urea and ammonium sulphate. Less nutrient losses and the balanced nitrogen and sulphur supply from Amidas fomulation could ensure consistently high yields of quality paddy with minimum environmental impact (Olowookere et al. 2017; Daphade et al., 2019; Yigermal et al. 2019).

On the other hand, Urea (46% N) is a formulation from anhydrous ammonia (NH3) with high nitrogen (N) analysis of 46% compared to all known N fertilizers. It is made available to the plant after contact with moisture within 48hours of application which is best achieved through soil incorporation. Urea is generally applied alone and is the fertilizer of choice when only N is needed in a fertilizer program. This may explain its inability to compete favorably with Amidas as a top-dress fertilizer as revealed in this study.

5.0 CONCLUSION AND RECOMMENDATIONS

Comment [i-[16]: At the end of the paragraph, the authors should highlight the limitations of the study, so that it becomes a practical implication and theoretical contribution to support the motivation of future studies.

Based on the results obtained, the following conclusions were made:

1. Significant improvement in rice paddy yield was realized in all study locations due to the fertilizer treatments. Grain yield improvement ranged from 4,280 kg/ha in Nyankpala to 2,440 kg/ha in Damongo.
2. The best two performing treatments in improving rice grain yield in both Nyankpala and Damongo were UNIK-L+AMI-L and ACT-L+AMI-L and ACT-LURE-L, in descending order.
3. At most locations, rice grain yield among the CropLiftBio foliar treatments was statistically similar.
4. Application of ACT+URE and UNIK+ACT without CropLiftBio foliar supplementation consistently demonstrated lower rice grain yields compared to the other fertilizer treatments in all study locations.
5. Rice paddy weight was however, not significantly impacted by the fertilizer treatments at any of the study locations.

Based on the conclusions raised, the following recommendations were made:

1. From the results of this study, Actyva fertilizers used as basal appear to be unsuitable for rice production in the savanna ecology of Ghana as these generally provided lower grain yields.
2. For maximum grain yield of rice in the ecology, Yara UNIK 15 (NPK 15:15:15) fertilizer is the most recommended. The basal application of UNIK 15 at 125 kg/ha and topdressing with Amidas at 125 kg/ha with CropLiftBio foliar supplementation will provide better yields for farmers than applying Actyva as topdress.
3. Where Amidas becomes unavailable, however, Urea (46 N) may be used as alternative topdressing product for moderate yield.
4. There is the need to investigate the efficacy of adding UNIK 15, or including Sulfan as possible topdress alternatives for rice production in the ecology.
5. For the smallholder situation where, double application may be a challenge, there is need to consider the efficacy of fertilizing rice with UNIK 15 alone at recommended rate, without any topdress application.

Competing interest

Authors have no conflict of interests

Acknowledgements

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Comment [i-[17]: There are still references such as journals, which do not include numbers (series) and doi links/urls.

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