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Influence of Rhizobium and Virus Inocula on Growth and Yields of Cowpea: A Mini-review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cowpea is a nutritional grain consumed especially in developing countries of the tropical and subtropical regions. It is prone to attack in its entire stages of growth by pathogens and pests such as bacteria, viruses, fungi and insects. Organisms, whether microbes, plants or animals interact both in isolated and complex systems. These interactions could be plant-plant, plant-microbe, microbe-microbe or microbe-microbe-plant interaction to complete the process of the food web. While some interactions are healthy and beneficial to the parties involved in the relationship, some others are unhealthy and harmful. This review has as its focus microbe-microbe interaction and effects on nodulation and yields of cowpea, with a view to examining the impacts on the sustainability of the food production system. A good knowledge of such interactions could help

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improve productivity and may allow the development of new strategies for plant protection and the control of parasites as well as for increasing crop yields. Hence this article assesses the influence of rhizobium and virus on cowpea nodulation and yields with a view to evaluating their contributory effects and assessing their individual potency in the interaction.

Keywords: Virus; bacteria; interaction; cowpea; nodulation.

1. INTRODUCTION

Cowpea is a major staple food in West Africa. It is an important crop because it serves dual roles of food and soil fertility restorer [1,2,3]. As food, it is a rich source of dietary protein for the people of West Africa, where about two-thirds of the world's production comes from [2,3]. As a fertility restorer, being a legume, it forms a symbiotic association with soil bacteria called rhizobia in the rhizosphere, where it obtains N-source and in turn provides C-source to the bacteria. This process provides a cheap source of N than nitrogenous fertilizers.

Apart from this kind of mutually beneficial relationship, there exists plant-microbe interaction which could result in an unhealthy relationship, which may trigger crop failure or food shortage. Such is the case between a virus and a crop plant. Viruses are a biological enigma and unlike bacteria, they are totally dependent on their host for existence without contributing anything in return. This is extremely intracellular parasitism,

Several studies have been conducted on the plant-microbe relationship in both isolated and complex systems, however, there is a possibility of interaction between different microorganisms that associate with the same crop plant.

A detailed understanding of such interaction could help improve productivity and may leads to the development of new frontiers in plant protection and control of parasites as well as for increasing crop yields. Hence this article examines the influences of virus and rhizobium on cowpea growth, nodulation and yields with a view to evaluating their contributory effects as well as assessing their individual potency in the interaction.

2. COWPEA: ORIGIN, DISTRIBUTION AND CULTIVATION

Cowpea is a nutritional grain consumed especially in developing countries of the tropical and subtropical regions. It is an important food and fodder legume in the sub-humid tropics of Africa. The source of domestication is controversial. Recent studies on cowpea origin and domestication believed that cowpea was domesticated with sorghum and pearl millet in Ethiopia because of their close association with these crops in early African farming [4,5]. However, Faris [6] believed cowpea originated from West/Central Africa based on the evidence of the presence of wild progenitors. Rawal [7] in his report supported Faris [6] and posited that West Africa is the center of origin while Nigeria is the center of domestication [8].

Cowpea is mostly grown for grain, however, they could also be grown as green leafy vegetables and fodder in Africa or as fresh pods in eastern Asia [9]. Worldwide, the majority of cowpea production (over 95%) occurs in sub-Saharan Africa, covering about 12.5 million hectares under cultivation in 2014 [10,11,12,3]. In addition, cowpea hay is a good source of forage for livestock, which plays an important role in feeding animals during the dry season in many parts of West Africa [13,14,3]. Owing to its nutritional benefit and resilience under changing climate, cowpea is an underutilized crop with potential to improve food security and alleviate poverty in sub-Saharan Africa [15].

Cowpea is prone to attack in their entire stages of growth by pathogens and pests such as bacteria, viruses, fungi and insects consequently resulting in low yields. The dry grain yields of traditional varieties have been low. The low yield in Africa, Asia and Latin America is generally attributed to poor husbandry, insect pests and diseases, drought and poor plant type [1,2,13,14].

3. RHIZOBIAL INTERACTION WITH COWPEA

Cowpea like many other legumes, form a symbiotic association with nodule bacteria (called rhizobia) present in most, if not all soils. Rhizobia possess a nitrogenase complex, an enzyme, which can transform atmospheric nitrogen into forms usable by the host plant. This process is termed biological nitrogen fixation (BNF). BNF is a recognized fundamental process in leguminous plants and for this reason, the association between legume and their appropriate rhizobia has been a focus of the investigation. While the host-plant supplies photosynthate to the bacteria for its competitive advantage in the rhizosphere, the bacteria in turn through an enzymatic process reduce atmospheric N into compounds assimilable by the host plant. Under conditions of N limitation, rhizobium bacteria infect leguminous plants, which then form root nodules. In the process, the bacteria present in the nodules (as bacteroids, differentiated forms of bacteria) fix atmospheric N and convert this into ammonia, which is used as a nitrogen source by the plant [9,1]. This attribute would allow adequate yield in N-deficient soils, where non-nodulating crops such as cereal would fail. Effective rhizobium-cowpea symbiosis fixes 150 Kg N/ha and supplies 80 – 90% of the host plant N-requirement [16]. The exploitation of this N-fixing mechanism provides a cheap way of N supply in poor and low fetidly soils of developing African countries. The effectiveness of a nodule in N-fixation and the extent of nodulation is determined by the compatibility of the host and rhizobial strain.

4. VIRAL INTERACTION WITH COWPEA

Viruses are biological mysteries. They are totally dependent on their host for existence and exhibit extremely specific intracellular parasitism. Viruses have the ability to infect, and can be transmitted from one host to the other [17,18]. Viruses are like particles that are infinitesimally smaller than a single cell and not visible through a light microscope. Most viruses are spread by insects, but some are spread mechanically through the exposure of plant wounds to infected sap. In insect transmission, plants become infected by the probing (sampling) and feeding activities of the insects such as aphids, thrips and leafhoppers that carry viruses (vectors). The virus has a devastating interaction with cowpea, causing a myriad of diseases and this has resulted in major constraints to increased production and food sustainability. The most effective method for the control of cowpea virus disease in Africa is by the adoption of resistant varieties [19]. This requires an adequate knowledge of the range of viruses and their strains occurring in the main cowpea-growing areas of Africa for effective control [19]. Although nine viruses are notorious for cowpea production in sub-Saharan Africa [20], only two (Cowpea Yellow Mosaic Virus, CYMV and Cowpea Aphid-Borne Mosaic Virus, CABMV) are considered important in terms of geographical distribution, pathogenic variation and yield losses [19]. These two viruses are indicted for yield losses of over 40% [17,21,22] and may even cause a complete crop failure, as in the case of CABMV in northern Nigeria [23].

5. EFFECTS OF RHIZOBIUM AND VIRUS ON COWPEA

The effects of the interaction of virus and rhizobium on cowpea have resulted in major depressions in the performance of cowpea in terms of growth, nodulation, biomass production, grain yield, and even in some physiological processes of cowpea such as N uptake (accumulation) and growth of rooting systems, as well as the time of infection.

5.1 Growth

Viruses have an impaired effect on the growth of cowpea. Tu and Ford [24] reported a reduction in nitrogenase activity as a result of the cowpea strain of TMV. Similarly, in a study conducted by Oyatokun et al. [25], the interaction of R25B (a promiscuous isolate of rhizobium) + CYMV produced a significantly higher growth response than R25B + CABMV at 5WAP while IRj 2180A (an isolate of *Bradyrhizobium japonicum*) + CYMV produced higher growth response than IRj 2180A + CABMV at 3WAP. This is an indication that CABMV has a more exerting potential and is more pathogenic than CYMV in depressing the growth of cowpea (Table 1).

5.2 Nodulation

Nodulation in cowpea was adversely affected by the virus due to its high prolificacy, thereby causing some changes in the physiological processes like reduced photosynthesis or increased respiration, imbalance auxins and enzyme level which directly or indirectly affected rhizobium/cowpea symbiotic relationship [8]. O'Hair and Miller [26] reported that the cowpea strain of Tobacco Mosaic Virus, TMV was associated with a reduction in the total number of nodules and their weights. These positions were also corroborated by Oyatokun et al. [25] who also reported depression in cowpea modulation as a result of inoculation with strains of cowpea yellow mosaic virus (CYMV) and cowpea aphid-borne mosaic virus (CABMV) (Table 1). However, R25B, a promiscuous isolate of rhizobium, exhibited a greater magnitude of nodulation in the interaction with the viral strains than IRj2180A, an isolate of *Bradyrhizobium japonicum,* although, this enhancement was not statistically different. The assertion by Wijesundara [27] indicated significant differences among rhizobial isolates with regard to infectivity and effectivity. Similarly, Taiwo et al. [28] reported that cowpea aphid-borne mosaic virus (CABMV) significantly affected cowpea nodulation resulting in fewer and smaller nodules formed as well as impairment of growth of root hairs and lateral roots (Fig. 1).

5.3 Biomass Production

The influence of rhizobium and virus in cowpea resulted in the reduction of biomass weight [25]. This agreed with the findings of Mali and Thottappily [18] that soybean plant inoculated with *Bradyrhizobium japonicum* and Alfa-alfa mosaic virus was said to have a reduced total dry weight of the plant.

5.4 Time of Infection

Oyatokun et al. [25] observed that the time of infection was inversely proportional to the cowpea performance response. He posited that growth response, nodulation and biomass production were slower when viral infection was carried out earlier than later (Table 2). In other words, greater havoc was done and became more devastating with the age of crop-plant when infection was early in the plant life. This is an indication of interference of the virus with some physiological and metabolic processes [26,24] of cowpea at the early growth stage causing greater damage than when infection was late. Similar results were reported by Chant [17] and Shoyinka [22] who reported that the earlier the infection, the greater the yield reduction. Even with infection as late as 6 weeks, significant yield reduction still occurs.

Table 1. Effect of inoculum strains on growth, nodulation, grain yield and N-uptake of cowpea

Inoculum	Plant height (cm)		Nodulation		Grain yield (g/plant)	N-uptake (g/plant)
	3WAP	5WAP	NN/PLT	NWT		
CONTROL	28.25ab	30.17a	25.79ab	437.90ab	0.91a	4.61c
R25B	29.17a	32.75a	28.92a	530.00a	0.98a	5.38a
IRj2180A	27.75ab	32.75a	26.17ab	459.10ab	0.98a	5.32b
CABMV	20.58c	19.83c	9.67d	218.70c	0.00d	1.17h
CYMV	21.25c	21.67c	11.71cd	240.40c	0.15c	1.42g
R25B+CABMV	27.25ab	26.42b	19.21bc	412.10ab	0.53abc	3.01e
R25B+CYMV	27.75ab	31.33a	24.71ab	435.00ab	0.79ab	3.78d
IRj2180A+CABMV	23.08c	29.08ab	18.00c	327.50bc	0.45bc	2.74f
IRj2180A+CYMV	25.92b	31.33a	21.25ab	329.10bc	0.36bc	0.36bc

Means that have the same alphabet are not significantly different at p < 0.5.
WAP = Weeks after planting
NN/PLT = Number of nodules per plant,
NWT = Nodules weight (mg/plant)
(Source: Oyatokun et al., 2013)

Table 2. Effect of time of inoculation on nodulation, biomass production and N-uptake of cowpea

Time of Inoc.	Nodulation		SDW	N-uptake (g/plant)
	NN/PLT	NWT		
Early	18.54b	436.95a	2.68b	20.32b
Late	22.67a	326.95b	3.60a	21.64a

Means that have the same alphabet are not significantly different at p=0.05.
NN/PLT = Number of nodules per plant,
NWT = Nodules weight (mg/plant)
SDW = Shoot Dry Weight (g/plant)
TIME OF INOC = Time of Inoculation
(Source: Oyatokun et al., 2013)

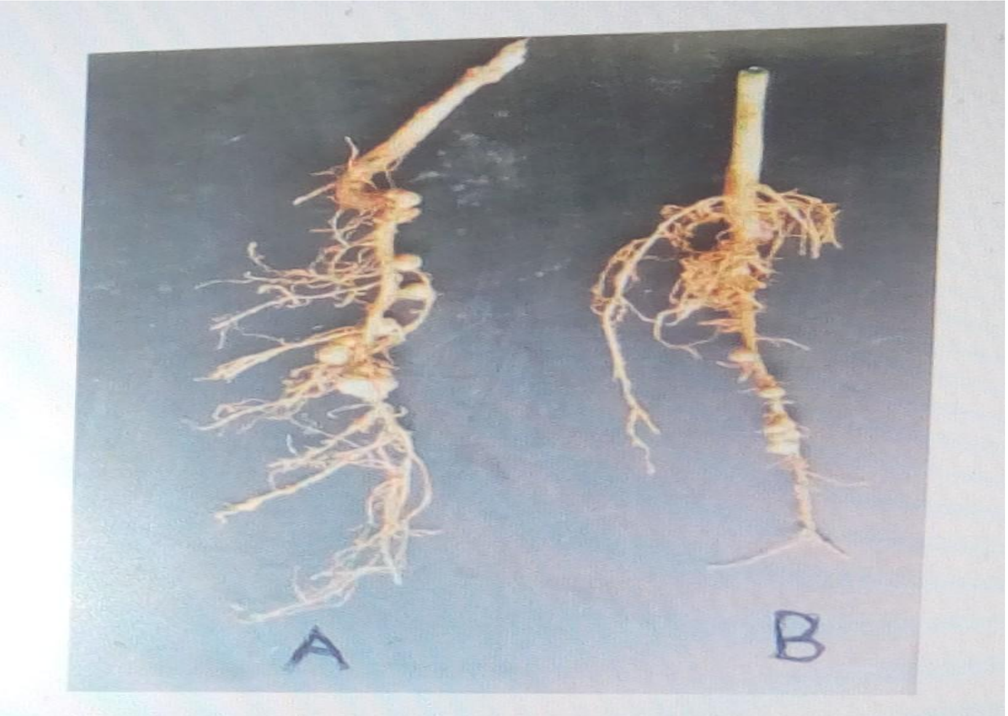

Fig. 1. Effect of virus on nodulation in roots of A: Healthy and B: CABMV = Cowpea Aphid-Borne Mosaic Virus-infected cowpea plants
(Source: Taiwo et al., 2014)

5.5 N-uptake

Oyatokun et al. [25] found a direct proportionality between N uptake and the time of viral infection. He reported that there was higher N-uptake when viral infection was late and vice versa (Table 2). This is a testimony of such facts that early interference with the plant's metabolic and physiological processes could affect some plant processes or output [26,24,28].

6. CONCLUSION

Viruses can and do interfere with the productive capacity of cowpea as a food crop and this may have a devastating impact on the supply and sustainability of the food production system. In spite of the presence of bacteria, infection by viruses still impair cowpea growth, nodulation and yield. The sure way of circumventing this menace of viral infection is by the use of resistant varieties from improved germplasm.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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