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Using wood vinegar to promote sustainable cowpea production in northern Ghana

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Abstract
Wood vinegar, a recommended biofertilizer, can improve organic farming by promoting crop growth and acting as a biocontrol agent. It contains pyroligneous acid, which serves as a bio-stimulant and biopesticide. The study evaluated the effectiveness and best methods of applying WV (i.e., 45 mL WV in 22.5 L of water per treatment) on the growth and yield of two cowpea varieties (Padituya and Wang-kae). It examined whether a combination of foliar and soil drenching (SD) application of WV would yield better results compared to other treatments: control (no WV), foliar application, and SD. The study used a randomized complete block (RCB) design and measured nodulation, root phenotyping, shoot biomass, pod, grain, and stover yields. Biomass data indicated that WV application increased shoot biomass compared to the control (no WV) in both Wang-kae and Padituya. WV had a more significant positive effect on pod and grain yields in Wang-kae than in Padituya. Additionally, the results revealed that the combined use of Foliar+SD generally led to reductions in biomass, nodulation, and grain yield.
In conclusion, WV application is a promising technology for increasing cowpea production, especially in low-input, external production systems without additional inputs. Additionally, applying WV through foliar spray and soil drenching appears to be effective, with greater benefits associated with soil drenching of WV.

Keywords: Cowpea grain yield, foliar application, organic farming, pyroligneous acid, nodulation, root phenotyping, soil drenching.

Introduction
Organic and agroecological practices improve soil health by enhancing structure, promoting biodiversity, increasing nutrients, reducing erosion, and building resilient, productive ecosystems—supporting sustainable agriculture and food security. Organic farming aid (OFA), also known as wood vinegar (WV), is a product derived from pyroligneous acid (PA) that can provide significant economic and environmental benefits when used properly. Its phytotoxicity can be utilized for herbicidal purposes when undiluted, while diluted forms encourage growth.

Wood vinegar has significant potential for sustainable agriculture and food security. Improved photosynthetic performance and growth of lettuces were observed when 0.2% diluted chestnut PA was applied through foliar spraying (Vannini et al., 2021). However, information on effective methods of applying WV to enhance crop productivity is limited within Ghana's cropping systems. Few studies have investigated the efficacy of OFA (i.e., WV) application methods in crop production, which hampers the development of wood vinegar technology for increasing plant productivity and restoring soil health in Ghana's cropping systems.

Material and Methods

Location: A field study was conducted in Nyankpala (Lat. 9.3937033; Long. -1.00458) in the Northern Region of Ghana during the 2021 cropping season. The experimental design was a randomized complete block design (RCBD) with four replications, and each plot measured 3.6×3 m. The treatments included four methods of WV application (i.e., 45 mL WV in 22.5 L water per treatment): control (with no WV), foliar application (Foliar), soil drenching (SD), and Foliar + SD. The test crop was two cowpea varieties (*Vigna unguiculata* var. Wang-kae and Padituya). Both cowpea varieties were sown at inter-row (ridge) and intra-plant distances of 60×20 cm, respectively.

The initial WV treatment was 24 days after planting (DAP), corresponding to the V4 stage. Afterwards, WV was applied weekly (i.e., every 7 days) until the pod-filled stage. Sampling for biomass, nodulation and root phenotyping were done at the different growth stages of the plant, including V4 (4-leaf), V8 (8-leaf), R2 (full flower), and R4 (full pod) stages.

Data Collection and Analysis: Data were gathered on biomass dry matter (shoot and root dry matter), nodulation (nodule number and nodule mass), root phenotyping (lateral root number and length, tap root length, lateral and tap root angles), yield components (pod load and pod yield), and overall yield (grain yield and stover yield). Data were analyzed using a Proc mixed model in SAS 9.4 at a 5% probability level, and means were separated with *Turkey-Kramer post hoc test.*

Results and Discussion

Figure 1: Photos from the field

Shoot Biomass

Table 1 shows the results for shoot dry matter for the cowpea varieties Wang-kae and Padituya.

Wang-kae: Shoot dry matter was significantly affected ($p < 0.001$) after WV application. SD yielded greater shoot dry matter than Foliar application and the combined Foliar+SD application of WV. Nodule mass was significantly ($p < 0.001$) enhanced by WV applied as Foliar and SD

compared to Foliar+SD. On the other hand, root dry matter and nodule number were not significantly improved by WV application.

Padituya: The application of WV did not enhance shoot- and root- dry matter, nodule number and nodule mass.

Table 1: Effect of WV application methods on dry matter (DM) and nodulation

Treatments	**Shoot DM**	**Root DM**	**Nodule Number**	**Nodule mass**
	(g/Plant)	**(g/Plant)**	**(g/Plant)**	**(mg/Plant)**
Variety: Wang-kae				
Control	5.64 b	0.51 a	10 a	71.2 ab
Foliar appl.	7.98 ab	0.63 a	10 a	81.1 a
SD	9.17 a	0.60 a	10 a	84.0 a
SD+Foliar application	6.12 b	0.51 a	10 a	62.9 b
Variety: Padituya				
Control	8.90 a	0.694 a	17.8 a	65.8 a
Foliar appl.	8.03 a	0.718 a	17.7 a	64.4 a
SD	8.72 a	0.662 a	17.5 a	59.3 a
SD+Foliar application	7.73 a	0.670 a	15.3 a	64.5 a

Values in columns, followed by the same small letter, are not significantly different at ($p < 0.05$) using the Turkey-Kramer post hoc test.

Yield and Yield Components

Pod yield and grain yield were significantly affected by the WV treatments (see Table 2).

Wang-kae: Foliar application of WV yielded the highest pod production, approximately 58% more than the control. Additionally, it produced about 50% more pods than Foliar + SD and 12% more than SD alone. Soil drenching with WV significantly increased pod yield compared to Foliar+SD and the control. Similarly, Foliar+SD of WV enhanced pod yield more than the control. Grain yield followed a similar pattern to pod yield, except the control showed a marginal increase over Foliar+SD of WV. Wood vinegar applied as Foliar, SD and Foliar+SD produced greater stover yield than the control.

Padituya: Pod yield associated with foliar application was significantly higher by approximately 27% and 33% compared to SD and control, respectively. Foliar+SD of WV produced a better pod yield of about 29% more than the control. Foliar application, SD, and the control all produced better grain yields than Foliar+SD of WV. The higher grain yield in the control, compared to Foliar+SD of WV, is contrary to the pod yield result. This is due to increased partitioning of pod yield to grain yield by the control treatment. The Pod Harvest Index (PHI) for the control treatment was approximately 74%, whereas that of Foliar + SD of WV was about 44%. Applying WV as Foliar, SD and Foliar+SD produced better stover yield than the control.

Table 2: Effect of WV application methods on pod yield, grain yield and stover dry matter (DM)

Treatments	**Wang-kae**	**Padituya**	**Wang-kae**	**Padituya**	**Wang-kae**	**Padituya**
	Pod yield (kg/ha)		Grain yield (kg/ha)		Stover yield (kg/ha)	
Control	1356 d	1585 b	873 c	1083 a	697 b	1770 b
Foliar application	2139 a	2110 a	1120 b	1116 a	1674 a	2032 a
SD	1910 b	1672 b	1265 a	1080 a	1369 a	2038 a
SD+Foliar Appl.	1423 c	2048 a	854 c	906 b	1321 a	2878 a

Values in columns, followed by the same small letter, are not significantly different at ($p < 0.05$) using the Turkey-Kramer post hoc test.

Conclusions and Outlook

Soil drenching and foliar application are the most effective methods of applying WV to attain higher yields in Wang-kae. Wang-kae cowpea producers who utilize either soil drenching or foliar application would realize greater profits or returns on investment.

With Padituya, WV application did not result in an appreciable increment in grain yield, but there was an additive effect of Foliar application of WV over the other treatments.

Finally, WV application promotes better biomass production in both Wang-kae and Padituya. Therefore, cowpea producers would benefit from improved stover yield, which is excellent fodder for farm animals.

Reference

Vannini, A., Moratelli, F., Monaci, F., Loppi, S., 2021. Effects of wood distillate and soy lecithin on the photosynthetic performance and growth of lettuce (Lactuca sativa L.). SN Appl. Sci. 3, 113. https://doi.org/https://doi.org/10.1007/s42452-020-04028-8