**RUFORUM Working Document Series (ISSN 1607-9345), 2018, No. 17 (1): 377-381.**
**Available from *http://repository.ruforum.org***

Research Application Summary

# Intercropping potato with grain legumes for enhanced productivity and climate change adaptation in smallholder farms, Kenya

Nyawade, O. S.,[1,2] Gitari, H.I.,[3,4] Karanja, N.N.,[2] Gachene, C.K.K.,[2] Geldermann, E.[3,5] & Parker, M. [1]

[1]The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), University of Nairobi, P.O.Box 30197, GPO, Nairobi, Kenya
[2]Department of Land Resources Management and Agricultural Technology, University of Nairobi, P.O.Box 30197, GPO, Nairobi, Kenya
[3]The CGIAR Research Program on Roots, Tubers and Bananas (RTB), International Potato Center, P.O. Box 25171, Nairobi, Kenya
[4]Department of Agricultural Science and Technology, School of Agriculture and Enterprise Development, Kenyatta University, P.O.Box 43844-00100, Nairobi, Kenya
[5]University of Applied Science Bingen (TH Bingen) Berlinstrasse 109, 55411, Bingen, Germany
**Corresponding Author:** shadnyawade@gmail.com

## Abstract

This study evaluated the effect of potato-grain legume intercropping systems on best land equivalent yield ratios, crop water productivity and net profits in field trials conducted in three agro-ecologies of Kenya: upper highland with seasonal rainfall of 592 mm and altitude of 2550 m, lower highland (505 mm, 1879 m) and lower midland (356 mm, 1522 m) in 2017 rainy seasons. Shangi and Unica the most common potato variety in Kenya, and a drought and heat tolerant variety, respectively, were grown alone and intercropped with the deep rooting legumes, Dolichos (*Lablab purperous*) and Lima bean (*Phaseolus lunatus*). Whereas the potato varieties had similar yields in the traditional highland growing zone, the heat and drought tolerant Unica performed significantly better in a typical semi-arid midland agro-ecology. Intercropping systems with lima bean and Unica potato variety increased crop water productivity by 38% compared to the pure Unica cropping system and maintained soil moisture content above 33% during flowering and tuberization stages at all sites. This resulted in significantly higher dry matter equivalent yields of 3.21 ± 0.12 $ha^{-1}$ compared to pure stands (1.98 ± 0.21 $ha^{-1}$) and when intercropped with Dolichos (1.11 ± 0.23 $ha^{-1}$) in the low midland zone. This system (Unica + Lima bean) recorded the highest net profits of USD 3,324 ± 143 $ha^{-1}$ across the three agro-ecologies. These results reveal a strong effect of Unica potato genotype and environment interaction, and show that intercropping a heat and drought tolerant potato variety with lima bean is an excellent option for improved resource use efficiency in non-mechanized smallholder farming systems. This strategy can diversify potato production to mid-elevation agro-food systems and mitigate events of climate change in traditional growing regions.

Keywords: Climate change adaptation, intercropping, Kenya, legumes, resource use efficiency, *Solanum tuberosum*

**Résumé**

Cette étude a évalué l'effet des systèmes de culture intercalaire de légumineuses avec pommes de terre sur les meilleurs rapports de rendement en terres équivalentes, la productivité de l'eau des cultures et les bénéfices nets dans des essais sur le terrain menés dans trois zones agro-écologiques du Kenya: les hautes terres avec des précipitations saisonnières de 592 mm et une altitude de 2550 m , basses terres montagneuses (505 mm, 1879 m) et basses terres moyennes (356 mm, 1522 m) pendant les saisons des pluies de 2017. Shangi et Unica, la variété de pomme de terre la plus commune au Kenya, et une variété tolérante à la sécheresse et à la chaleur, respectivement, ont été cultivées seules et associées aux légumineuses à enracinement profond, Dolichos (Lablab purperous) et haricot de Lima (Phaseolus lunatus). Alors que les variétés de pommes de terre avaient des rendements similaires dans la zone de culture traditionnelle des hautes terres, l'Unica, résistant à la chaleur et à la sécheresse, a obtenu résultats significativement meilleurs dans une zone agro-écologique moyenne typique semi-aride. Les systèmes de cultures intercalaires avec le haricot de Lima et la variété de pomme de terre Unica ont augmenté la productivité de l'eau des cultures de 38% par rapport au système de culture Unica pur et ont maintenu la teneur en eau du sol au-dessus de 33% pendant les étapes de floraison et de tubérisation sur tous les sites. Ceci a entraîné des rendements équivalents en matière sèche significativement plus élevés de 3,21 ± 0,12 $ha^{-1}$ par rapport aux peuplements purs (1,98 ± 0,21 $ha^{-1}$) et en cas de culture intercalaire avec des Dolichos (1,11 ± 0,23 $ha^{-1}$) dans la zone des basses terres moyennes. Ce système (Unica + haricot de Lima) a enregistré les bénéfices nets les plus élevés de 3 324 ± 143 $ha^{-1}$ USD dans les trois zones agro-écologiques. Ces résultats révèlent un fort effet du génotype de la pomme de terre Unica et de l'interaction avec l'environnement, et montrent que la culture intercalaire d'une variété de pomme de terre tolérante à la chaleur et à la sécheresse avec le haricot de Lima est une excellente option pour améliorer l'efficacité de l'utilisation des ressources dans les petits systèmes agricoles non mécanisés. Cette stratégie peut diversifier la production de pommes de terre vers les systèmes agroalimentaires de moyenne altitude et atténuer les événements de changement climatique dans les régions de culture traditionnelles.

Mots clés: Adaptation au changement climatique, cultures intercalaires, Kenya, légumineuses, utilisation efficace des ressources, Solanum tuberosum

## Introduction

Despite its high demand in the tropical lowlands, potato (*Solanum tuberosum*) production remains an activity restricted within the humid highlands where there are low temperatures and high rainfall amounts. Potato has shallow fibrous root systems which are concentrated in the upper (0-30 cm) soil profile, making the crop highly vulnerable to water deficit (Nyawade *et al.,* 2018). Appreciable decrease in tuber yield occurs if a balance between soil temperature, soil moisture content and crop nutrient uptake is not attained (Ferreira and Goncalves, 2007). Simple and sustainable strategies that can optimize soil temperature, crop water productivity and nutrient use efficiency in potato growing areas therefore become necessary. Intercropping potato with legume cover crops has been proposed (Nyawade, 2015; Gitari *et al.,* 2018; Burke, 2017). This is due to legumes' ability to biologically fix atmospheric nitrogen and exploit soil moisture at greater depths (Giller, 2015; Burke, 2017).

It is in view of this background that this study tested the potential of potato-legume intercropping systems to increase potato yields, crop water productivity and net profits in humid, sub-humid and semi-humid Zones of Kenya. We hypothesized that no significant effect of intercropping exist on crop water productivity and that no yield difference is exhibited between intercropping and potato monocultures. Quantifying crop water productivity is important for the design of soil water management strategies in rain-fed potato.

## Materials and Methods

Shangi, the farmer preferred potato variety in Kenya, and Unica, heat and water stress tolerant variety were intercropped with: dolichos (*Lablab purpureous*) and lima bean (*Phaseolus lunatus*) in a 1:1 spatial arrangement in Nyandarua, Kirinyaga and Kabete. Soil moisture and soil temperature were quantified with Onset HOBO Sensor probes. Legume yields were converted to potato DM equivalents for comparison. Data were analyzed using Genstat and means were separated with Fishers protected at $p \leq 0.05$.

**Effect of legume intercropping systems on potato equivalent yields.** Highest potato dry matter equivalent yield (3.43 ± 0.04 to 12.63 ± 0.08 t/ha) was recorded in pure stand of lima bean, followed by lima bean Unica (2.99 ± 0.04 to 11.86 ± 0.03 t/ha) and was lowest in pure stand of Shangi (0.27 ± 0.04 to 3.25 ± 0.02 t/ha) (Table 1).

**Profitability of potato-legume intercropping systems.** Net income was highest in Unica lima bean system (US$ 3,543 ± 88 to US$ 19,721 ± 620/ha) followed by Shangi lima bean (US$ 3,165 ± 143 to US$ 18,484 ± 469/ha and was lowest in pure stand of Shangi (US$ 787 ± 118 to US$ 13,074 ± 78) (Table 2).

**Table 1. Effect of legume intercropping systems on potato equivalent yields**

| | Kabete | Ol-Kalou | Kipipiri | Kirinyaga |
|---|---|---|---|---|
| | Potato DM equivalent yield (t/ha) | | | |
| Shangi pure stand | 3.01 ± 0.09$^{a}$ | 3.25 ± 0.02$^{d}$ | 2.78 ± 0.08$^{c}$ | 0.27 ± 0.04$^{a}$ |
| Unica pure stand | 2.91 ± 0.01$^{a}$ | 4.40 ± 0.01$^{e}$ | 3.89 ± 0.07$^{d}$ | 1.14 ± 0.04$^{b}$ |
| Dolichos pure stand | 6.67 ± 0.11$^{d}$ | 1.45 ± 0.03$^{a}$ | 1.10 ± 0.04$^{a}$ | 1.95 ± 0.05$^{e}$ |
| Lima bean pure stand | 12.63 ± 0.08$^{f}$ | 11.83 ± 0.06$^{g}$ | 7.72 ± 0.08$^{f}$ | 3.43 ± 0.04$^{h}$ |
| Shangi + Dolichos | 4.22 ± 0.10$^{b}$ | 1.60 ± 0.04$^{b}$ | 1.49 ± 0.08$^{b}$ | 1.35 ± 0.05$^{c}$ |
| Unica + Dolichos | 4.74 ± 0.07$^{c}$ | 2.76 ± 0.03$^{c}$ | 1.63 ± 0.04$^{b}$ | 1.70 ± 0.05$^{d}$ |
| Shangi + Lima bean | 8.79 ± 0.08$^{e}$ | 11.34 ± 0.08$^{f}$ | 6.95 ± 0.08$^{e}$ | 2.81 ± 0.06$^{f}$ |
| Unica + Lima bean | 8.89 ± 0.09$^{e}$ | 11.86 ± 0.03$^{g}$ | 6.98 ± 0.05$^{e}$ | 2.99 ± 0.04$^{g}$ |
| LSD | 0.1416 | 0.0664 | 0.1608 | 0.0653 |

Means followed by different letters within a site indicate significant differences at $p \leq 0.05$. Means are presented with standard deviation.

**Table 2. Net income of potato-legume cropping systems**

| | Kabete | Ol-Kalou | Kipipiri | Kirinyaga |
|---|---|---|---|---|
| | US$/ha | | | |
| Unica pure stand | 8,628 ± 288$^{bc}$ | 13,074 ± 78$^{e}$ | 11,547 ± 214$^{d}$ | 3,387 ± 127$^{e}$ |
| Shangi pure stand | 8,937 ± 252$^{bc}$ | 9,644 ± 92$^{d}$ | 8,301 ± 232$^{c}$ | 787 ± 118$^{a}$ |
| Dolichos pure stand | 3,785 ± 159$^{a}$ | 2,697 ± 77$^{a}$ | 1,618 ± 54$^{a}$ | 2,772 ± 170$^{cd}$ |
| Lima pure stand | 9,167 ± 324$^{bc}$ | 9,744 ± 102$^{d}$ | 7,798 ± 209$^{c}$ | 4,379 ± 123$^{f}$ |
| Unica + Dolichos | 9,263 ± 376$^{bc}$ | 8,514 ± 72$^{c}$ | 4,805 ± 96$^{b}$ | 2,452 ± 134$^{c}$ |
| Shangi + Dolichos | 8,125 ± 278$^{b}$ | 5,027 ± 92$^{b}$ | 4,406 ± 122$^{b}$ | 1,696 ± 34$^{b}$ |
| Unica + Lima bean | 10,394 ± 539$^{c}$ | 19,721 ± 620$^{g}$ | 7,961 ± 234$^{c}$ | 3,543 ± 88$^{e}$ |
| Shangi + Lima bean | 9,810 ± 345$^{bc}$ | 18,484 ± 469$^{f}$ | 7,716 ± 104$^{c}$ | 3,165 ± 143$^{de}$ |
| LSD | 1028 480.4 | 520 271 | | |

Values are given with standard deviation of means. Means followed by different letters within a site indicate significant differences at $p \leq 0.05$.

## Conclusion

Intercropping a heat tolerant potato variety with lima bean can diversify potato production to mid-elevation agro-food systems. This strategy can mitigate events of climate change in traditional potato growing regions.

## Acknowledgements

This research was jointly undertaken under the CGIAR Research Programs on Climate Change, Agriculture and Foods Security (CCAFS); and Roots, Tubers and Bananas (RTB). The authors acknowledge the International Potato Center (CIP) - Sub-Saharan Africa for supporting this study through grants from the Federal Ministry for Economic Cooperation and Development (BMZ) of Germany. This paper is a contribution to the 2018 Sixth African Higher Education Week and RUFORUM Biennial Conference.

## References

Burke, J.J. 2017. Growing the potato crop. Vita, Equity House, Upper Ormond Quay, Dublin 7, Ireland.

Ferreira, T.C. and Goncalves, D.A. 2007. Crop-yield/water-use production functions of potatoes (*Solanum tuberosum* L.) grown under differential nitrogen and irrigation treatments in a hot dry climate. *Agric. Water Manage* 90: 45–55.

Giller K. E. 2015. Nitrogen Fixation in tropical cropping systems. 2nd Ed., CABI, Wallingford, 423pp.

Gitari, H.I., Gachene, C.K., Karanja, N.N., Kamau, S., Nyawade, S., Sharma, K. and Schulte-Geldermann, E. 2018. Optimizing yield and economic returns of rain-fed potato (*Solanum tuberosum* L.) through water conservation under potato-legume intercropping

systems. *Agricultural Water Management* 208: 59-66.

Nyawade, S. O., Karanja, N. N.. Gachene, C.K.K., Schulte-Geldermannc, E. and Parker, M. 2018. Effect of potato hilling on soil temperature, soil moisture distribution and sediment yield on a sloping terrain. *Soil and Tillage Research* 184: 24–36. https://doi.org/10.1016/j.still.2018.06.008

Nyawade, O.S. 2015. Effect of potato (*Solanum tuberosum* L.) cropping systems on soil and nutrient losses through run-off in a humic nitisol. MSc. Thesis. University of Nairobi, Kenya.