*Research article*

# An Assessment of Soil Chemical Properties and Yields of Black Gram, Using GIS, in a Selected Area of Myanmar

**HTAY HTAY OO***
*Yezin Agricultural University, Myanmar*
*Email: htay.agro96@gmail.com*

**KHIN MAR OO**
*Yezin Agricultural University, Myanmar*

**SWE SWE MAR**
*Yezin Agricultural University, Myanmar*

**NAING NAING MOE**
*Yezin Agricultural University, Myanmar*

Received 14 December 2018 Accepted 10 July 2019 (*Corresponding Author)

**Abstract** In Myanmar, pulses are a very important crop with great potential for export. Black gram (*Vigna mungo* L.) is one of the predominant pulse species grown, with planting after the harvest of monsoon rice in the winter season. Understanding the spatial variability of soil chemical properties is critical for improving the productivity of pulses and ensuring sustainable farming practices. However, a systematic assessment on the spatial variability of pulses yield has not been conducted. Therefore, this study was carried out to examine the variability of black gram yields in relation to soil chemical properties, at Kyee Inn Village, Pyinmana Township, central Myanmar from May 2017 to March 2018. Eighty composited soil samples were collected across the study area and analyzed for common soil chemical properties. Sixty seven farmers were surveyed as sample respondents to determine yields and management practices. Interpolation allowing overlay mapping of variations in black gram yields on soil chemical properties was accomplished using ArcGIS software. It was observed that these soil chemical properties and black gram yield varied considerably throughout the study area. Slight variability was observed in total nitrogen content. The pH value of the soils was moderately acidic to moderately alkaline with pH values of 5.48 to 7.58. The fields were characterized by low levels of soil organic matter and total phosphorus. The variation in black gram yields, ranging from 0.16 to 1.97 ton per hectare, is probably a result of the high variation of total soil nitrogen and phosphorus content. The results suggest that to improve soil fertility and sustain and improve black gram yields, it is very important to apply organic matter, nitrogen and phosphorus in parts of the study area.

**Keywords** black gram, GIS, overlay mapping, organic matter, total nitrogen and phosphorus, yield, sustainable farming

## INTRODUCTION

In Myanmar, pulses are an important crop with great potential for export, and the rapid growth in production has been driven by a huge demand from India. Black gram (*Vigna mungo* L.) is one of the most favored species farmed in Myanmar, in terms of acreage and production output. Pulses are important for crop intensification, diversification and conservation of natural resources as well as the sustainability of farm production systems, because of their short growth duration, dense crop canopy and versatility (Katiyar and Dixit, 2010). However, black gram is generally produced in fields that have a high degree of variability in soil type, topography, soil moisture and other major factors that can affect crop yield.

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GPS based soil fertility maps have been prepared by a number of different government and private sector organisations for different areas of Myanmar. Remote sensing (RS), geographical information systems (GISs) and geo-statistics are tools becoming progressively more central to fields of research like agriculture (Bocchi et al., 2000; Basso et al., 2001). Scientific information relating spatial variability to distribution of soil properties is critical for farmers attempting to increase effectiveness of fertilizer use and maximize crop productivity. Fertilization of a crop based on specific parameters of soil fertility, should also result in minimalizing fertilizer inputs without reducing yield (Jalali, 2007). Geo-statistics have been used to analyse the spatial variability of soil properties and crop yield (Stevenson et al., 2001). However, a systematic assessment on the spatial distribution and variability of pulse yields and soil chemical properties has not been conducted in Myanmar. Evaluating the spatial variability of pulse yields in relation to the chemical properties of soils allows micro-adjustments that are essential for regional planning purposes, promoting sustainable pulse production and increasing levels of productivity.

## OBJECTIVES

The present study was carried out to examine the current status and spatial variability of soil chemical properties and the relationship of this to black gram yield. Maps of the study area were generated to illustrate this relationship.

## METHODOLOGY

### Study Site and Data Collection

The research was carried out in central Myanmar. The study site is Kyee Inn Village, Pyinmana Township, which lies between 19°70'66" - 19°72'62" N and 96°22'43" - 96°25'73" E and examined a total study area of 486 ha, from May 2017 to March 2018 (Fig. 1). Farmers in the study area usually practice what can be described as a monsoon rice-pulse cropping pattern. The mean annual rainfall is approximately 1420 mm and daily mean temperature, 26.8°C. The study area was superimposed with 300 m × 300 m geographic grids using geographical information system (GIS) tools, and comprised 80 sample grid points (Fig. 2). Among these 80, only those grids where farmers had cultivated black gram were included in the survey. Accordingly, 67 farmers were selected as sample respondents and information about average yield per acre and crop management practices was collected through interview and structured questionnaire. For soil analysis, each grid had three soil samples taken, these at a depth of 0-15 cm. The 3 samples from each grid were combined to give a composite sample. To avoid undesirable effects due to fertilization in the growing period, samples were taken after harvest.

Sensors were on a DJI Phantom 4 drone and Litchi software was used to interpret information. Flight altitude was 120 meters and the drone images were combined and processed using pix 4D software for digitizing and relating these to the digital base map of the study area. ArcGIS software from Environmental Systems Research Institute (ESRI) was used to produce maps of the spatial distribution of yield and soil chemical properties. Interpolation and overlay mapping were generated using Inverse Distance Weighting (IDW) and the Radial Basis Function (RBF) which are deterministic interpolation methods in the Arc GIS 10.5 software according to Meng et al. (2013).

### Statistical Analysis

All relevant data were subjected to analysis using the Statistix 8 program. Mean, standard deviation, and standard errors were determined for each of the soil properties considered as well as soil moisture content and yield of black gram, using descriptive statistics. The variability of each property was measured by coefficient of variation (CV) expressed as a percentage.

### Laboratory Analysis

Laboratory analysis was conducted for the composite soil samples. This involved air-drying, pounding, and sieving (2.0 mm sieve) and storage at 4°C in a cool room. Soil pH was measured using a digital pH meter in soil to water solutions, consisting of a 1:5 suspension, after 30 minutes of mixing (Hesse, 1971). Total soil nitrogen was determined using the Kjeldahl digestion, distillation and titration method (Bremmer, 1982) whereas total soil phosphorus was analyzed using spectrophotometer measurement of blue molybdatephosphate complexes under partial reduction with ascorbic acid (Jackson, 1958). Soil organic matter was determined using the wet digestion method (Walkley, 1934).


**Fig. 1 Location of the study area**

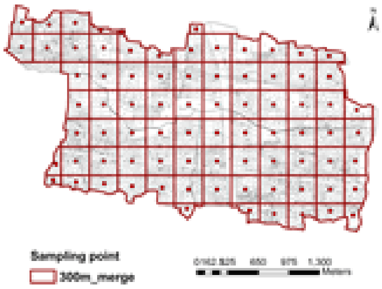


**Fig. 2 Grid sampling points**

## RESULTS AND DISCUSSION

### Spatial Variation in Soil Chemical Properties

The coefficients of variation (CV) were grouped into three categories; these being, least variable (<15%), moderately variable (15-35%) and extremely variable (>35%). That is, the higher the CV the more variable the soil property measured. Data were subjected to analysis by descriptive statistics to determine significant differences between the black gram yield, soil moisture content (MC) and soil chemical properties. A large variation in soil chemical properties was observed across the study area. In terms of variation in soil properties, total nitrogen shows the highest variability with a CV of 68.52%, followed by soil organic matter with a CV value of 34.56%, whereas variations for soil pH and total phosphorus show least variability with CVs of 5.13% and 6.25% respectively (Table 1). The results indicate that there is natural variation, which is often compounded by nutrient management practices used by farmers. This has implications for black gram production since soil chemical and soil water content variability can be expected to lead to variability in crop yield.

### Soil pH

**Table 1 Descriptive statistics of yield, soil water content and soil chemical properties**

| Variables | Unit | Minimum | Maximum | Mean | SE | SD | CV% |
|---|---|---|---|---|---|---|---|
| Estimated Yield | ton $ha^{-1}$ | 0.160 | 1.970 | 0.840 | 0.043 | 0.364 | 43.348 |
| pH | -log $[H^{+}]$ | 5.480 | 7.580 | 6.244 | 0.038 | 0.320 | 5.127 |
| Soil Water | % | 1.790 | 9.640 | 4.928 | 0.182 | 1.545 | 31.358 |
| Organic Matter | % | 0.200 | 1.700 | 0.893 | 0.036 | 0.309 | 34.562 |
| Total Nitrogen | % | 0.010 | 0.330 | 0.114 | 0.008 | 0.078 | 68.520 |
| Total Phosphorus | % | 0.017 | 0.024 | 0.019 | 0.001 | 0.001 | 6.249 |

*SE: Standard error; SD: Standard deviation; CV: Coefficient of variation*

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The soil pH of the study area was found to be acidic to slightly alkaline and ranged from 5.48 to 7.58 (Table 1). Black gram prefers soil with a pH in the range 5.5 - 6.5, tolerating 4.5 - 7.5 (Katiyar and Dixit, 2010). Thus, the variability of soil pH may be assumed to not represent a major contributing factor to variation in black gram yield.

**Soil Organic Matter and Soil Water**

The estimated average yield for black gram in the study area was obtained through surveying farmers, by both interview and structured questionnaire. From the sample plots, black gram yields range from 0.16 to 1.97 ton $ha^{-1}$ (Table 1). These data were overlain on to maps of soil organic matter and soil moisture for the study area (Fig. 3a and 3b).

The black gram cultivars commonly used in Kyee Inn Village, Pyinmana Township are Yezin-2, Yezin-5 and Yezin-6 (Fig. 2). In general, yield exhibited the following characteristics. The grid points in the eastern part of the study area produced higher yields, ranging from 0.99 to 1.48 ton $ha^{-1}$. Moreover, the sample grid points where the black gram cultivars were Yezin-2 and Yezin-6 had higher yields than area where Yezin-5 was planted. According to the Department of Agricultural Research (DAR), the potential yield of Yezin-5 (1.6 - 2.0 ton $ha^{-1}$) is lower than that of Yezin-2 (2 - 2.4 ton $ha^{-1}$) and Yezin-6 (2.4 - 3.2 ton $ha^{-1}$) when grown under same conditions. Thus, the study affirms that Yezin-2 and Yezin-6 should be grown instead of Yezin-5 in upcoming seasons to increase productivity.

Soil organic matter and soil water have very important functions that correlate positively to nutrient availability and retention. It should also be taken into consideration that the nutrient input from soil contributes considerably to crop nutrition (Fu et al., 2010). The amount of soil organic matter is highly dependent on a range of ecological factors such as climate, soil type, vegetative growth, topography in which it occurs as well as land use and management and tillage of the soil and intensive cropping (Rawal et al., 2018). The spatial distribution of organic matter and soil moisture (in percent) exhibits a gradual percentage increase from the northeast portion to the southwest portion of the study area, where the highest content for both are found. One possible reason for this is the slightly higher elevation of the northern portion with accumulation of organic matter and moisture often favored at lower levels. The average soil organic matter content of study area varies from 0.2 to1.7% with a mean value of 0.893%, which is very low when soil organic matter greater than 2.6% is considered to provide good nutrient storage (Purdie, 1998). In the overlay mapping, all sampling grid plots had insufficient levels of soil organic matter and there is high variation in percentage content. This suggests the low yields for black gram, and spatial variability of these yields may be attributed to the poor crop management practices, with a failure to systematically apply organic and inorganic fertilizers.

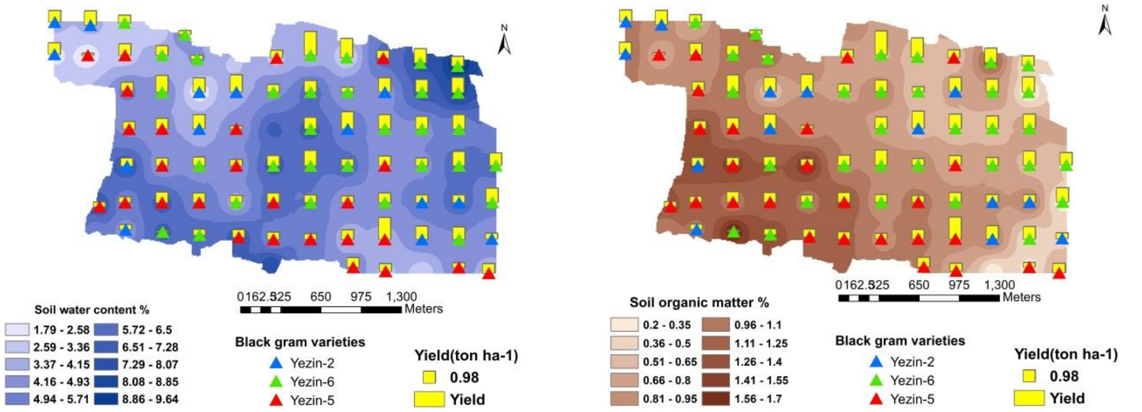


**Fig. 3 Overlay mapping of distribution of yield and cultivars for (a) soil water content and (b) soil organic matter in Kyee Inn Village, Pyinmana Township, 0.98: mean yield of black gram in ton $ha^{-1}$**

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## Total Nitrogen and Total Phosphorus

Soil fertility is one of the major constraints to agricultural production in tropical countries, including Myanmar. Examining the current soil fertility status is important because it could provide valuable information relating to crop research (Khadka et al., 2017). Soil nitrogen is one of the most important plant nutrients, and of all nutrients, the most frequently deficient (Havlin et al., 2010). The total nitrogen content varies from 0.01% to 0.33% with the mean value of 0.114% in this study (Fig. 4a). The critical value of total N in soil is 0.12% (Shah et al., 2008). The overlay mapping, show most of the sampling grid plots have low levels of total nitrogen. This low nitrogen content may relate back to the insufficient level of soil organic matter content in the study area.

The percentage value of total phosphorus ranges from 0.017 to 0.024% with a mean value of 0.019%. In most soils, P content is very low in the surface layer and represents less than 1% of total P. However the total P content of a soil may vary widely and depend on factors such as organic matter content, climatic conditions, parent materials and application of fertilizers (Mansour et al., 2014). In the overlay mapping, about half of the sampling area is medium in range, whereas the rest of the study area is in a lower range for phosphorus content (Fig. 4b).

The yield variations in black gram already mentioned also may be related to the variations in soil nitrogen and phosphorus content. Low levels of phosphorus can be ameliorated by replenishing with fertilizers which contain high amounts of available phosphorus. In the overlay mapping of Fig. 4.a and Fig. 4.b, it can be seen that most sampling grid plots not only have low levels of soil nutrients but are sown with different black gram cultivars. Therefore, results suggest the spatial variability of black gram yield can be attributed to the poor crop management practices, such as the insufficient application of nitrogen and phosphorus fertilizers, in combination with the selection of poor yielding cultivars for planting.

(a) (b)

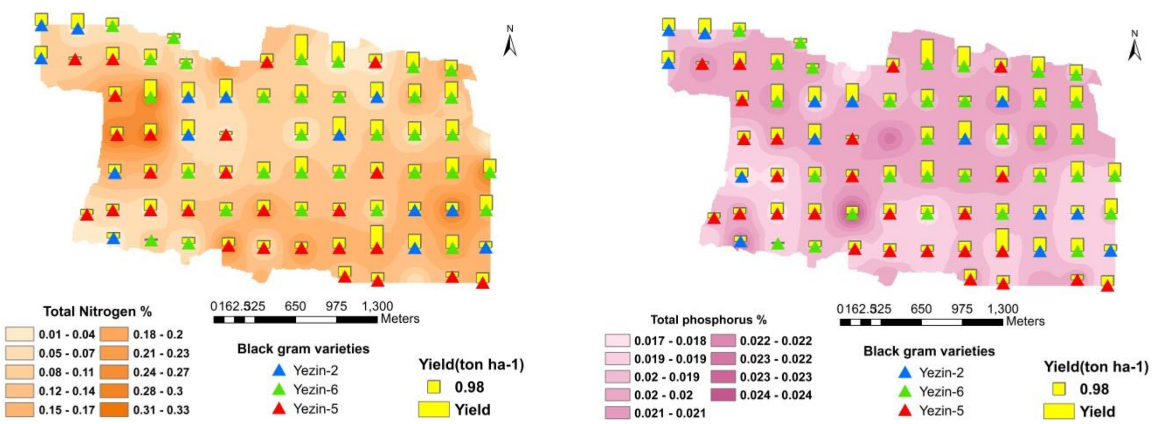


**Fig. 4 Overlay mapping on distribution of yield and cultivars on to (a) total nitrogen and (b) total phosphorus in Kyee Inn Village, Pyinmana Township, 0.98: mean yield of black gram in ton ha$^{-1}$**

## CONCLUSION

Results clearly show that most of the area under black gram cultivation has low levels of organic matter, with total soil nitrogen and phosphorus also below desired levels. Due to continuous tillage and the failure to add organic matter, and with minimal nutrient supply from either natural or artificial sources, low levels of these nutrients pertain in the study site. The pH range of soils in the study area should not present a problem for the black gram cultivation, and cannot be assumed as a major factor contributing to the spatial variation in yields of black gram. The results suggest that to improve soil fertility and sustain black gram production, it is very important to apply organic matter and phosphorus, particularly in certain parts of the study area. The overlay maps provide a readymade source of information about the status soil fertility and can serve as a spatially accurate decision making tool for successful black gram cultivation. It can be concluded from the present study that GIS based soil fertility maps help farmers by providing spatially specific recommendations regarding fertilizer application, improving crop production and ensuring greater sustainability.

## ACKNOWLEDGEMENTS

We would like to acknowledge the Japan International Cooperation Agency for Technical Cooperation Project (JICA-TCP) at Yezin Agricultural University for providing financial and technical support. We wish to extend sincere gratitude to Pro-Rector Dr. Kyaw Kyaw Win, and Dr. Kazuo Watanabe for their generous technical support and valuable advice in this study. Our appreciation is also extended to the authorized staff at the Department of Agriculture (DoA) and Department of Agricultural Land Management and Statistics (DoALMS) for data provision.

## REFERENCES

Basso, B., Ritchie, J.T., Pierce, F.J., Braga, R.P. and Jones, J.W. 2001. Spatial validation of crop models for precision agriculture. Agric. Syst., 68, 97-112.

Bocchi, S., Castrignano, A., Fornaro, F. and Maggiore, T. 2000. Application of factorial kriging for mapping soil variation at field scale. Eur. J. Agron., 13, 295-308.

Bremmer, J.M. and Mulvaney, C.S. 1982. Nitrogen-total. In: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.), Methods of Soil Analysis, Part 2-Chemical and Microbiological Properties, ASA-SSSA, Madison, WI. 595-624.

Fu, W.J., Tunney, H. and Zhang C.S. 2010. Spatial variation of soil nutrients in a dairy farm and its implications for site-specific fertilizer application. Soil Tillage Res., 106, 185-193.

Havlin, H.L., Beaton, J.D., Tisdale, S. L. and Nelson, W.L. 2010. Soil fertility and fertilizers, An introduction to nutrient management. 7th Edition, PHI Learning Private Limited, New Delhi, India. 516.

Hesse P.R. 1971. A text book of soil chemical analysis. John Murray, London.

Jalali, M. 2007. Spatial variability in potassium release among calcareous soils of western Iran. Geoderma, 140, 42-51.

Jackson, M.L. 1958. Soil chemical analysis. Prentice-Hall. Engle-wood Cliffs, N.J. 498.

Katiyar, P.K. and Dixit, G.P. 2010. Genetic divergence in Indian black gram (*Vigna mungo*) cultivars. Indian J. Agric. Sci., 80 (3), 242-243.

Khadka, D., Lamichhane, S., Shukra, R.S. and Pant, B.B. 2017. Evaluation of soil fertility status of regional agricultural research station, Tarahara, Sunsari, Nepal. Eurasian J. Soil Sci., 6 (4), 295-306.

Mansour, A.S., Latif, A.A., Zaho, S.M.E. and Abdullah, I.N. 2014. A case study of the total and available phosphorus concentration in libyan agricultural soils in different depths and seasons in long term chemical and animal manure fertilization. International Journal of Research Studies in Biosciences (IJRSB), 2, 1-9.

Meng, Q., Liu, Z. and Borders, B.E. 2013. Assessment of regression kriging for spatial interpolation comparisons of seven GIS interpolation methods. Cartogr. Geogr. Inf. Sci., 40, 28-39.

Purdie, B. 1998. Understanding and interpreting soil chemical and physical data. In: Moore, G. (Ed.), Soil Guide: A Handbook for Understanding and Managing Agricultural Soils, Agriculture Western Australia Bulletin, No. 4343, Department of Agriculture, Perth, Australia.

Rawal, N., Acharya, K.K., Bam, C.R. and Acharya, K. 2018. Soil fertility mapping of different VDCs of Sunsari district, Nepal using GIS. Int. J. Appl. Sci. Biotechnol., 6 (2), 142-151.

Shah, A.L., Islam, M.R., Haque, M.M., Ishaque, M. and Miah, M.A.M. 2008. Efficacy of major nutrients in rice production. Bangladesh J. Agril. Res., 33 (3), 639-645.

Stevenson, F.C., Knight, J.D., Wendroth, O., van Kessel, C. and Nielsen, D.R. 2001. A comparison of two methods to predict the landscape-scale variation of crop yield. Soil Tillage Res., 58, 163-181.

Walkly, A. and Black, I.A. 1934. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37, 29-38.

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