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Variable rate phosphorus fertilization experiment based on on-line visible and near infrared soil sensing

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Soil phosphorus is an important nutrient particularly for root and seed development, and deficiency of soil P could result in poor crop yield. However, over-application of Phosphorous causes waste of fertilizer and contamination to the environment. Variable rate (VR) fertilization may allow for a better phosphorous management in the soil, if within field variability in soil available P (P_av) can be characterized at a desirable fine scale. Visible and near infrared (vis-NIR) spectroscopy has been proven to be fast, cheap and non-destructive tool for the measurement of P_av. On-line vis-NIR sensors enable the collection of high resolution data on P_av with acceptable accuracy. The aim of this paper was to compare the economic and environmental benefits of VR phosphorous fertilization based on on-line vis-NIR soil sensing (OVR) against uniform rate (UR) and traditional precision farming variable rate (TVR). A trial plot experiment consisting of 9 plots was designed and implemented in a field with spring barely in 2013. Triplication plots (24 m width) for each of the three fertilization methods (OVR, UR and TVR) were randomly laid out in the field. Prior to the fertilization experiment, an on-line vis-NIR measurement was carried out to measure within field variation in P_av. Fertilizer input (P_2O_5 in kg ha^{-1}) and yield output of each plot was measured to run a basic cost-benefit analysis. The validation of the on-line measurement with an independent validation set showed moderate measurement accuracy of P_av (R^2= 0.72, RMSEP = 0.55 mg/100g and RPD = 1.99). The lowest amount of P_2O_5 was recommended and applied in OVR plots, which indicated a reduction of fertilizer use by 40 and 54 kg ha^{-1}, as compared to UR and TPF method, respectively. Small yield difference was observed between the three treatments, although UR plots showed a slightly higher yield (6.990 kg ha^{-1}). However, ANOVA analysis resulted in a smaller F value of 0.22 than F critical (3.22), which allows the conclusion that the differences of yield between the three treatments are insignificant at 5% confidence ($p < 0.05$) level. The cost-benefit analysis showed the OVR method to provide comparable margin to TVR method, as only extra £2 per ha was calculated with OVR. A much larger margin of about £31 per ha was obtained with the innovative the OVR method, as compared to the TVR. A longer term experiment is still underway in the same to understand and confirm the mechanism and agronomic link if any between fertilizer input and crop growth and yield, as practical experience indicated that more than one cropping season is needed to record actual crop response to phosphorous application. It can be concluded that a clear environmental benefit can be achieved by using the innovative OVR concept. However, a longer term study is needed to prove the economic benefit, as compared particularly to TVR.

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