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# Weed Spatial Variability in Field Condition as Predicted by Kriging

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## SUMMARY

A field experiment was conducted at the research farm of ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh during *kharif* 2012 to check the suitability of Randomized Block Design for weed control trials. Soil samples were collected from 33 grids (each of size 5 × 5 $m^2$) of experimental field before *kharif* 2012 for weed seed bank study. Weed count data was recorded in the study season. Weed distribution maps were obtained through geo-statistical technique called kriging. These maps were prepared by using both weed count data in field as well as data obtained from weed seed bank study. *Ludwigia parviflora* accounted for approximately 50-60% of the total weed counts in the study season. However, total weed count data was used for modelling and kriging purposes. Result showed that the distribution of weeds is random in field situation and do not show any direction of gradient and thus violates the assumption of Randomized Block Design which is generally used for conducting weed control trials.

*Keywords:* Geo-statistics, Kriging, Semivariogram, Spatial variability, Weed count.

## 1. INTRODUCTION

The experimental design dictates the inferences drawn from an experiment (Onofri *et al.* 2010). Thus, a proper design, based on research objective, is the basis of a successful experiment. Agriculture requires suitable design for different field and laboratory experiments. In agricultural field experiments, blocking is followed to minimize the experimental error and different treatments in different plots pertaining to a block are allocated along with the randomization and replication principles for a valid estimate of the experimental error.

Similarly, weed control trials are conducted in Randomized Block Design (RBD). Purpose of blocking in these experiments is to get homogenous material for a block and this variation among blocks is eliminated from the error and thereby efficiency is increased. However, weeds are not uniformly distributed on arable fields (Marshall 1988) and thus do not follow a definite pattern within a field. Thus, intensity of various weed species germinating in an agricultural field differs greatly from place to place and do not show any systematic direction of gradient as is generally noticed in case of fertility gradient. Hence, it contributes to major part of the variability and thus leads to very large standard error. Further, the nature of the weed population occurring in the weedy check (control treatment) plot may also differ greatly from those occurring in the treated plots. Most blocking in weed management experiments has been practiced in relation to soil type or topography because there is rarely any prior information about the spatial distribution of the weed in a particular field. Hence, in seedbank sampling studies, spatial heterogeneity has been accepted as a major source of variability, resulting in coefficients of variation from 60 to 100% or higher (Forcella *et al.* 1992). Keeping all these facts in view, the present study was planned to check the suitability of Randomized Block Design (RBD) for weed control trials by using the weed spatial variability maps obtained through kriging.

Kriging approach takes into account the spatial dependence between different points on

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the surface. It is a weighted average of observed phenomenon and is the estimator that also gives an estimate of the variance. Furthermore, kriging confirms that the estimation is unbiased and has minimum variance (Cressie 1991 Kristensen and Ersboll 1995).

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Experiment was conducted in one hectare field at ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh in the *kharif* season of 2012. Treatments were not applied to the field since many years. The field was full of weeds in the experimental year. Experimental field was divided into 33 grids, each of size 5 × 5 $m^2$ and soil samples were taken from these grid points just before *kharif* season. Center point of each grid was considered for taking Global Positioning System (GPS) observations.

### 2.2 Weed Seed Bank Study

Soil samples were analyzed for weed seed bank study. A weed seed bank stores weed seeds to preserve genetic diversity; hence it is a type of gene bank. The method of studying and identifying weed seed composition is called weed seed bank study. This includes the method of observing germination from seeds of the soil sample and identifying the weed seedling. Hence, weed seed bank estimation is used to predict the possibility of future weed infestations in the field. Data on number of weed seedling from seed bank study were recorded for further analysis.

### 2.3 Weed Count Data

In *kharif* season, 30 days after emergence of weeds (DAE), actual weed counts from all the grids were recorded. This was repeated again after 30 days of first count. The counting was done using quadrate of size 0.25 $m^2$ from 5 places (4 corner and 1 center place) in each grid. Thereafter, it was extrapolated for 25 $m^2$ area for each grid. *Ludwigia parviflora* accounted for approximately 50-60% of the total weed counts in the study season. Apart from this, species like *Ammannia baccifera, Echinochloa colonum, Cyperus iria, Commelina communis, Phyllanthus niruri* were also present in the field. However, total weed count data were used for modelling and kriging purposes.

### 2.4 Statistical Analysis

Present study was conducted in four steps: (1) Transformation of weed counts to ensure normality; (2) calculation of semivariogram which describes the variation between weed counts separated by a certain distance; (3) fitting a model to the semivariogram; and (4) estimate weed density distribution on the rest of the field using parameters from the semivariogram model.

Weed distribution map was prepared using geo-statistical method, kriging. This method assumes the variables to be normally distributed but weed counts generally follows negative binomial distribution (Marshall 1988, Wilson and Brain 1991). Therefore, square root transformation was performed to normalize the distribution of weed counts. After transformation, a semivariogram was calculated, which describes the spatial variation between measurements separated by a certain distance (Heisel *et al.* 1996). Thereafter, a model was fitted to empirical semivariogram with various functions (Webster and Oliver 1990), e.g. often used are spherical, exponential and gaussian models (Heisel *et al.* 1996). After modelling the variogram, next step is the kriging which is defined as the weighted average of observed value with in a neighborhood that provides the best linear unbiased estimator of the response function with minimum variance. Models were fitted to semivariogram using Variowin software and weed distribution maps were prepared using proc krige2d procedure in SAS 9.2 (SAS/STAT module). Soil seed bank data and actual weed count data were analyzed separately for preparing distribution maps.

## 3. RESULTS AND DISCUSSION

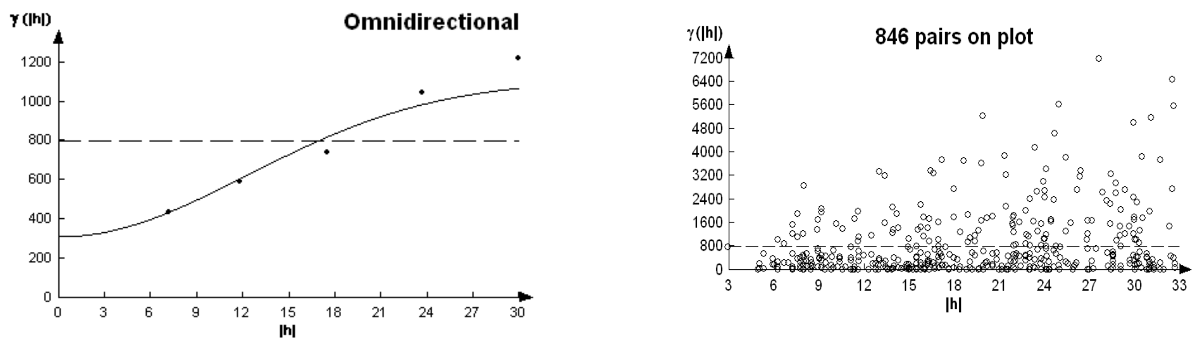
Three models were fitted to the semivarigram i.e. spherical, exponential and gaussian. Parameters for different models are given in the following Table 1.

**Table 1**. Parameters of the fitted models used in the estimation of weed maps

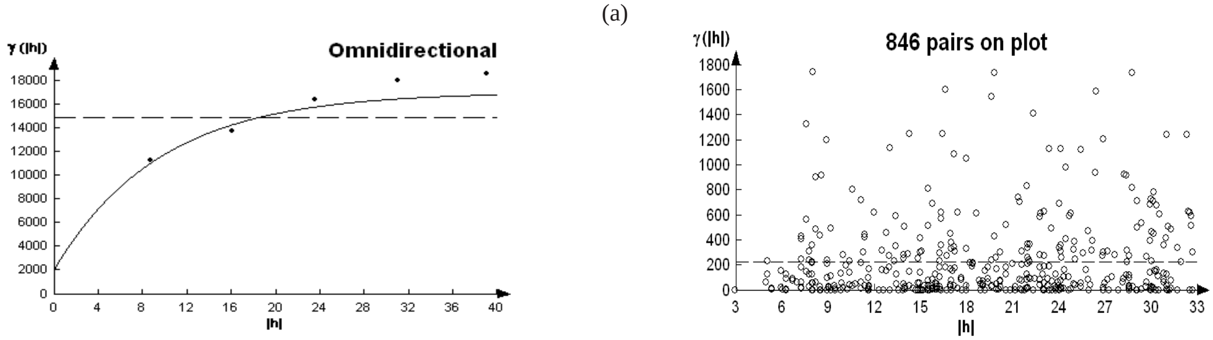
| Data | Model | IGF | Nugget | Range | Sill | Lag |
|---|---|---|---|---|---|---|
| Weed count _30 DAE | Sph | 0.0424 | 136 | 25.2 | 800 | 5 |
| | Exp | 0.0694 | 128 | 30 | 800 | 5 |
| | Gauss | **0.0137** | 312 | 30 | 800 | 5 |
| Weed count_60 DAE | Sph | 0.0147 | 1650 | 21.6 | 15000 | 5 |
| | Exp | **0.00551** | 2100 | 28.4 | 15000 | 5 |
| | Gauss | 0.0269 | 5100 | 27.6 | 13800 | 5 |
| Soil seed bank | Sph | 0.0129 | 2400 | 24.8 | 15000 | 5 |
| | Exp | **0.00347** | 2850 | 32 | 15000 | 5 |
| | Gauss | 0.0215 | 6900 | 31.6 | 13800 | 5 |

Sph-Spherical model; Exp-Exponential model; Gauss-Gaussian model; IGF- Indicative Goodness of fit.

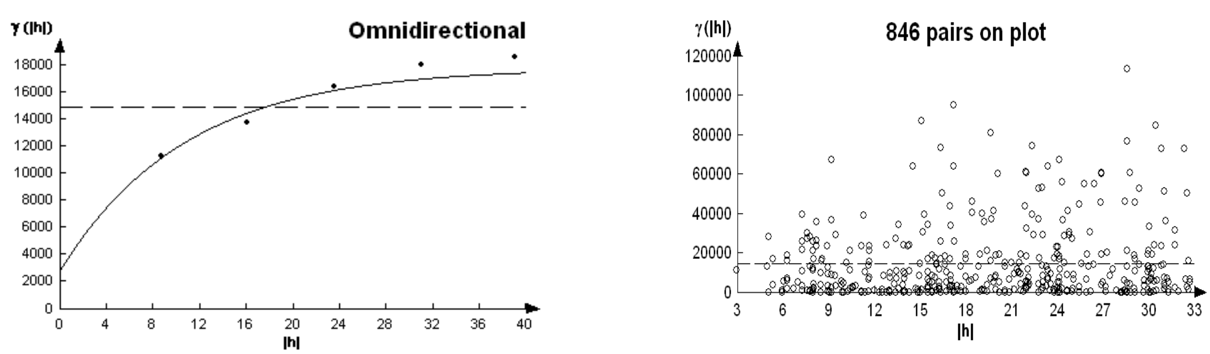
Best model is one for which Indicative Goodness of fit (IGF) value is minimum. For weed count data (30 DAE) gaussian model is found to be the best with IGF value as 0.0137, Nugget effect as 312, range as 30 and sill as 800 with effective lags 5. For weed count data (60 DAE) and soil seed bank data, exponential model was found to be best among three models. IGF value for exponential model is 0.00551 and 0.00347 for weed count data (60 DAE) and soil seed bank data respectively. Fig. 1 shows the fitted model for weed count data (30 DAE), weed count data (60 DAE) and soil seed bank data respectively.




(a)



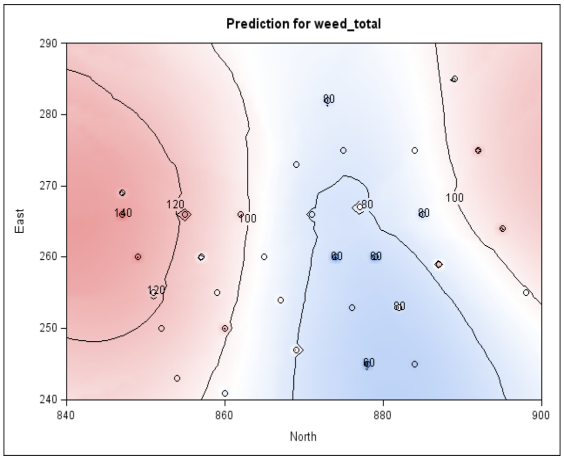

(b)



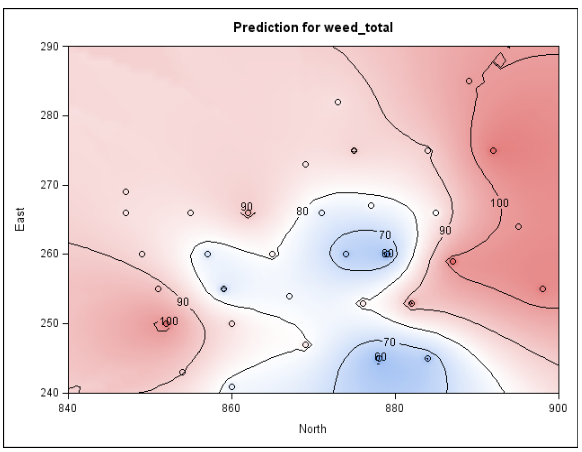

(c)

**Fig. 1.** Semivariogram and plots of data pairs for the transformed value of total weed count at (A) 30 DAE, (B) 60 DAE and (C) Soil seed bank

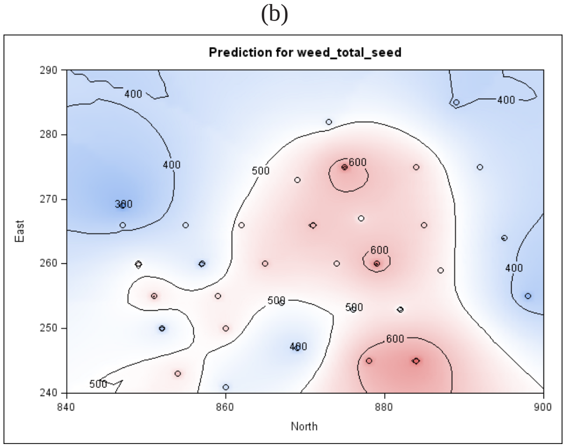
Parameter values obtained from model fitting of semivariogram were then used to prepare weed distribution maps by kriging. Fig. 2 shows the weed maps for three types of weed count data.




(a)




(b)




(c)

**Fig. 2.** Prediction surface using weed count data at (A) 30 DAE and (B) 60 DAE and using (C) Soil seed bank data

Dark red colour shows high intensity of weeds while very light blue colour depicts the presence of very few weeds in the field. In the present study, actual weed count data does not agree with the soil seed bank data (A B & C). Reason could be that the weed seeds which are present in the soil in high density could not find favourable conditions (temperature, moisture, soil depth etc.) for their growth and development in that season, while other seeds may be in dormant conditions. Some weed species like *Ludwigia parviflora* find favourable condition and emerge as major weed flora in that season. Prediction surface obtained using weed count data at 30 DAE and 60 DAE are almost identical but in some places they have some minor differences where water logging condition was present at the time of recording observation at 30 DAE, while at later stage (60 DAE) there were more weed population in the same places in the absence of water logging condition. Distribution maps of different weeds were also obtained which also showed the random pattern of spatial distribution of weeds.

Analysis showed that the distribution of weeds is random and violates the assumption of Randomized Block Design (RBD) which is originally framed to account for variation arising from source for e.g. soil fertility or topography other than treatments. Therefore, use of RBD in weed control trials may ignore the major contributor of the variation resulting over or under estimation of treatment effects, which may subsequently lead to misleading inferences. In this situation, there is need of experimental design which can take care of spatial randomness pattern of weed population over the field. Study revealed that kriging may be useful tool to prepare weed distribution maps of different fields and may provide additional information which can be used to improve the existing design to obtain precise estimates.

## REFERENCES

Andreasen, C., Streibig, J.C. and Haas, H. 1991. Soil properties affecting the distribution of 37 weed species in Danish fields. *Weed Res.,* **31,** 181-187.

Cousens, R.D., Brown, R.W., McBratney, A.B. and Moerkerk, M. (2002). Sampling strategy is important for producing weed maps: a case study using kriging. *Weed Sci.*, **50**, 542-546.

Cressie, N.A.C. (1991). *Statistics for Spatial Data*. John Wiley and Sons, New York, 900 pp.

Finney, D.J. (1973). Transformation of observations for statistical analysis. *Cotton Grow. Rev.,* **50**, 1-14.

Forcella, F., Wilson, R.G., Renner, K.A., Dekker, J., Harvey, R.G., Alm, D.A., Buhler, D.D. and Cardina, J. (1992). Weed seedbanks of the US corn belt: magnitude, variation, emergence and application. *Weed Sci.,* **40,** 636-644.

Heisel, T., Andreasen, C. and Ersboll, A.K. (1996). Annual weed distributions can be mapped with kriging. *Weed Res.,* **36,** 325–327.

Heisel, T., Ersboll, A.K. and Andreasen, C. (1999). Weed mapping with Co-kriging using soil properties. *Precision Agric.,* **1(1),** 39-52.

Kristensen, K. and Ersboll, A.K. (1995). The use of geostatistical methods in variety trials, where some replicates are unreplicated. *Fifth working seminar on statistical methods in variety testing.* Zakopane, Poland.

Lori, J.W. (2005). Sampling to make maps for site-specific weed management. *Weed Sci.*, **53(2),** 228-235.

Marshall, E.J.P. (1988). Field-scale estimates of grass weed populations in arable land. *Weed Res.,* **28**, 191-198.

Onofri, A., Carbonell E.A., Piepho, H-P, Mortimer, A.M. and Cousens, R.D. (2010). Current statistical issues in weed research. *Weed Res.,* **50**, 5-24.

Rew, L.J., Whelan, B. and McBratney, A.B. (2001). Does kriging predict weed distributions accurately enough for site-specific weed control? *Weed Res.,* **41**, 245–263.

Webster, R. and Oliver, M.A. (1990). *Statistical Methods in Soil and Land Resource Survey*. Oxford University Press, Oxford.

Wilson, B.J. and Brain, P. (1991). Long-term stability of distribution of *Alopercurus myosuroides* Huds. within cereal fields. *Weed Sci.,* **31,** 367-373.