Optimizing Weed Control by Integrating the Best Herbicide Rate and Bio-agents in Wheat Field

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Abstract

Objectives: Study of reducing the rates of a new generation herbicide verdict in combination with some biocontrol components under the field condition of Moscow to suppress Avena fatua and broad-leaved weeds and consequently maintaining satisfactory crop yield under intensive technology. Method/Statistical analysis: Field experiment were laid out to appraise the efficacy of reduced concentrations of a post-emergence herbicide verdict in combination with biocontrol agent to suppress three major weeds (Chenopodium album, Avena fatua and Capsella bursa-pastoris) in wheat field under the condition of Non-chernozem zone, Moscow region. Findings: Shown labeled concentration 0.3 kg/ha+ bio-agents was effective in reducing total weed populations. This study showed that a desirable weed reduction in wheat was achieved when intermediate herbicide rate 0.3 kg/ha+ and bio-agents were used, that was comparable to the result which achieved for registered verdict dose as 0.5 kg/ha+. Hence, despite the higher weed reduction efficacy was obtained with herbicide in registered label dose plus biocontrol agent, but the differences were not significant in comparison with below herbicide dose 0.3 kg/ha+. Meanwhile, the best energy output (90.3 GDj/ha-1), agricultural efficiency (19.9%) and wheat grain yield 7.80 t/ha-1 were achieved when reduced rate 0.3 kg/ha+ combined to bio-agent were applied. Application /Improvement: Cutting of herbicide dosage without compromising grain yield can cause to less environmental pollution and lower production costs, besides, can reduce weed population desirably.

Keywords: Agronomical Efficiency, Energy Output, Reduced Herbicide Rate, Weed, Wheat Yield

1. Introduction

Weed is the most important factor in wheat grain yield losses1. Crops often have challenges with weeds by competition on water, nutrition and other elements through competition2.

The important purpose of managing weeds is to reduce the weeds at a desirable or appropriate level, but not to eliminate them comprehensively. In most case, satisfactory weed reduction and favorable yields were obtained, when herbicides are operated at reduced concentrations3–11, and, lower rates of chemical components are often sufficient to reduce weeds. To ensure considerable weed management under undesirable technique of cropping factors, producers recommended higher than necessary concentrations. Therefore, it is not often necessary using full herbicide rate (labeled rate)12. Additionally, modern weed science insists ecological approaches based on controlling weeds below threshold levels13.

Herbicides are the dominant tool used for weed management in modern cropping systems; they are highly effective on most weed populations but are not a complete solution to the complex challenge that weeds present. The overuse of chemical agent has led to the evolution of herbicide resistance14,16. Herbicides in Labeled concentrations are often elected to ensure desirable weed suppression over a wide range of environmental conditions and weed species17.
50% rate of tralkoxydim suppresses higher than 85% of narrow leaf weeds in barley. Also tralkoxydim at reduced rates can provides an acceptable reduction of wild oat. Survey of various herbicides (fluroxypyr; diflufenican + MCPA and Clopyralid + 2, 4-D) efficacy in different concentrations to suppress weeds in cereals revealed that 85% of Galium tricornutum was suppressed for the higher herbicide rate, but bellow-labeled 50% rate as the lowest herbicide concentration also diminished weeds populations to 82%. Nevertheless, majority of herbicide at low concentrations are often adequate to reduce weed density without yield reduction.

Scientists emphasize the importance of investigating the dynamics of weed communities to broaden the function of cultural and biological control approaches. The integrating reduced herbicide doses with other management strategies, such as biological methods, could also markedly enhance the odds of desirable weed suppression. Hence, weed control system with the purpose of the reducing herbicide application needs to integrate multiple techniques. Control strategies involve mowing, herbicides, and biological components. Mowing reduces, but does not eliminate weeds, and the application of herbicides to large areas with rough terrain is difficult and so costly. Hence, the using biological agents seem to be the most pragmatic control option.

Increasing number of herbicide-resistant weeds makes it obvious that frequent using the single tool for pest suppression not just leads to a preponderance of the most problematic species, but can basically shift the genetic composition of their populations. However, integrating control practices emphasizes the use of multiple strategies to address the causes of weed fitness. Consequently, investigating for alternative cultural and biological practices has intensified. Biological strategies recommended modern approaches to the application of chemicals that create new environmental factors weed control practices. Biological management of weeds is defined as environment-friendly, using bio-agent components towards weeds.

Weed management by the using biological components has received much interest in the last decades. Majority of countries need bio-herbicides registration according to pesticide legislation before initial application. In present study, survey the optimizing weeds reduction by the reducing doses of new generation of herbicide in integration with some bio-agents under the field condition of Moscow region was the main purpose.

2. Material and methods

2.1 Experimental Design

Field experiments were carried out on improving the strategies for post-emergence weed suppression in winter wheat (Triticum aestivum) were performed as an intensive farming technology during 2012 - 2014 in the Moscow Research Institute of Agriculture, Moscow area, Russia. The site was located at 55° 45′ N, 37°37′ E and 200 m altitude. Samples were taken randomly from different spots at 0 - 15 cm to record the initial characteristics of the experimental soil. The soil type was a loamy with 1.7% organic matter and a pH of 5.3. The experimental field was plowed before planting seeds, and the field was prepared by roller harrowing. Disk operation also conducted; for changing soil pH, Dolomik powder 5 t/ha was applied to the seedbed.

2.2 Climatic Condition

During 2012 - 2013 years’ vegetative season there was measurable rainfall, mainly precipitation; daily average soil and atmospheric temperature was high; moisture deficiency was obtained in the middle of vegetation season. Weather condition of winter 2014 was non-typical in comparison with average for Moscow region. Soil was frozen up to 41 cm; snow level was very high – up to 40 cm. Figure 1 shows the average rainfall and mean monthly temperature data recorded in vicinity of the experimental farm.

![Average monthly rainfall and monthly temperature during 2012 – 2014 Moscow region.](image)

2.3 Field Layouts Details

Biological agents [bio-herbicide, bio-fertilize and biofungicide with anti-stress activity to chemical treatments in combination with the various doses of verdict (0, 0.2, 0.3 and 0.5 kg/ha) adjuvant 500 cc was mixed to herbi-
3. Result and Discussion

3.1 Weed Control Efficacy During 2013 - 2014

Combination of reduced herbicide doses and other management techniques could favorably enhance the odds of desirable weed suppression. Number of weeds and dry weight were mostly for effect of the reduced rates of herbicide in combination with bio-agents, weeds population reduced mainly when herbicide 0.5 kg/ha\(^{-1}\) + bio-agents was applied compared with other treatments, moreover, a satisfactory reducing *Cenopodium album*, *Capesella bursa-pastoris* and also *Avena fatua* were obtained with below-registered rate as intermediate concentration (Figures 2–5). Appropriate weed reduction might be occurred with reduced herbicide rates and also providing favorable suppression during critical periods.\(^{10,21,22,23}\) Therefore, it is not always essential to use full herbicide rate.\(^{32}\)

The higher efficacy was reached with the labeled herbicide rate + bio-agents. Additionally, the lowest concentration 0.2 kg/ha\(^{-1}\) combined with bio-agents had a significantly lowest control efficacy on declining of weed species: *Cenopodium album*, *Capesella bursa-pastoris* and *Avena fatua*. Although the highest weed control was achieved with the registered dose of verdict, below labeled herbicide dose (intermediate dose) + bio-agents also provided a desirable reduction about all three weeds varieties (Figures 2–5). As in our study, the efficacy of cutting rates of herbicide groups has been determined by other authors.\(^{49–52}\)

According to the results of this study, despite the highest weeds control efficacy was obtained with the registered dose of herbicide, intermediate rate 0.3 kg/ha\(^{-1}\) + bio-agents also caused acceptable weed reduction about entire weeds varieties (Figures 2–5). There are examples where herbicides are used at doses that do not often cause such high weed suppression. Indeed, using herbicide rates can vary markedly between countries and enterprises. For instant, doses of herbicide in Australia are often 50\% of that in other nations. However, the labeled rate for diclofop in Australia is 375 g ai ha\(^{-1}\) compared with 640 g ai ha21 in the United States and 900 g ai ha21 in France.\(^{33}\) Moreover, 28\% of the crop fields in Canada manage weeds with reduced dose of herbicides.\(^{34}\) In addition to dose cutting, environmental variability under field conditions for
soil residual herbicides can result in lower than normal doses of herbicides being used to weed populations.

Biological agents cannot replace chemicals, or any other weed control tools, hence, biological agents should be combined to other control techniques. Using bio-agents can have acceptable weed control efficacy integrated with chemicals. Biological components will probably have long-time advantages to natural areas. Bio-agent alone is not a means by which to achieve weed suppression. However, using biological components for weeds management should not be assessed as a primary weed control practice, but can be illustrated as an integrated in other weed management techniques as it has been also revealed by authors.

![Figure 2](image.png)

**Figure 2.** Weed Density affected by treatments 30 days after applications in 2013 (plant/m²).

*Abbreviations: T1, T2, T3 are herbicide dose 0.5, 0.3 and 0.2 L/ha⁻¹ respectively plus bio-agents.*

![Figure 3](image.png)

**Figure 3.** Weed density affected by treatments 30 days after applications in 2014 (plant/m²).

*Abbreviations: T1, T2, T3 are herbicide dose 0.5, 0.3 and 0.2 L/ha⁻¹ respectively plus bio-agents.*
3.2 Biological Efficiency of Treatments During 2013 - 2014

Estimating the biological efficiency of verdict combined to bio-agents 30 days after application demonstrated that herbicide 0.5 kg/ha\(^{-1}\) combined to bio-agents reduced weeds dry weight 90 - 91% and density 86.6 - 87.5% compared to the control during 2013 - 2014 experimental years, additionally, biomass and density of weeds were desirably declined in comparison with control when intermediate concentration 0.3 kg/ha\(^{-1}\) was applied (Table 1).

Regarding to the result, it is recommended to reduce herbicide rates combined to biocontrol agents in order to improve weed control programs, this point in addition to control weeds in a proper way can diminish environmental pollution, weeds resistance and achieve sustainable cropping system. Some investigations have proved appropriate weed suppression and also desirable yields, when chemicals are operated at lower than registered rates \(^{10,11}\).

Results of this study might be due to the integration of biological agent to herbicide. It is necessary to realize that a bioherbicide or any biological weed control techniques are not an analogue of a chemical. Nevertheless, bioherbicides or any other biological practices have to be combined to other control tools in an integrated weed management approach. In this regards, some scientists have illustrated that low rates of agents could result in rapid evolution of herbicide resistant \(^{59,60}\). Reducing herbicide concentration is better combined to other techniques.

3.3 Responses of Yield and Yield Component to the Treatments During 2012 - 2014

Field data revealed that wheat yield was increased with the different verdict doses combined to the bio-agents as compared to control. The highest level of wheat yields
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7.8 t/ha\(^{-1}\) during 2013 and 7.57 t/ha\(^{-1}\) during 2014 was achieved while below labeled dose of verdict 0.3 kg/ha\(^{-1}\) plus bio-agents were used, and the lowest grain yield 6.87 t/ha\(^{-1}\) during 2013 and 6.51 t/ha\(^{-1}\) during 2014 was achieved in the control (no application) (Table 2). Grain weight factor is a significant component and individual grain weight could be raised and reduced\(^{61}\).

Herbicide applied at 0.5 kg/ha\(^{-1}\) plus bio-agent recorded as high productive biological yield 17.80 t/ha\(^{-1}\) and gluten content 31.95 %, 1000 grain weight 46.32 gram and protein content 18.02% as were obtained at registered dose for 2013 (Table 2). The highest biological yield is probably due to proper weed suppression and wheat get desirable nutrition. Also stated that desirable weed control increases biological yield\(^{62}\).

In experiment 2014, biological yield 17.80 t/ha\(^{-1}\),1000 grains weight 46.20 gram and gluten content 32.20% were achieved as the highest levels when verdict 0.3 kg/ha\(^{-1}\) as an intermediate dose plus biological agents were used. Despite, there is no difference between experimental treatments about harvest index, but it is indicated the 44.77% harvest index as the best level was recorded when herbicide rate 0.3 kg intermediate/ha\(^{-1}\) and bio-agent were used.

Weeds interfere with crops through competition, resulting in direct losses to crops and enhancing cropping costs\(^{63}\). In this study, wheat yields were related to weed population and biomass as denoted (Table 2), and increasing wheat productivity with the various herbicide rates could be provided to decline weed competition\(^{11,64}\). Fairly acceptable wheat and wheat traits and also weeds

### Table 1. Biological efficiency of treatments 30 days after applications during 2013-2014

| Treatments | yr  | Density | Dry weight | Percent of weed reduction compared to control |
|------------|-----|---------|------------|-----------------------------------------------|
|            |     | plant/m\(^2\) | gr/m\(^2\) | Density | Dry weight |
| T 1        | 2013 | 7.5    | 0.6       | 87.5    | 91        |
|            | 2014 | 8      | 0.7       | 86.6    | 90        |
| T 2        | 2013 | 13     | 1.3       | 79      | 82        |
|            | 2014 | 13     | 1.2       | 78.3    | 83        |
| T 3        | 2013 | 27     | 2.3       | 55      | 65.6      |
|            | 2014 | 25     | 2.6       | 58      | 62.5      |
| T 4        | 2013 | 60     | 6.7       | -       | -         |
|            | 2014 | 60     | 7         | -       | -         |

Abbreviations: T1, T2, T3 and T4 are herbicide dose 0.5, 0.3, 0.2 L/ha\(^{-1}\) plus bio-agents and control respectively.

### Table 2. Influence of treatments on wheat and wheat component in 2013-2014

| Treatments | yr  | Gluten content % | Protein content % | 1000 grain weight | Biological yield (t/ha\(^{-1}\)) | Wheat yield (t/ha\(^{-1}\)) | Harvest index % |
|------------|-----|------------------|-------------------|-------------------|----------------------------------|----------------------------|----------------|
| T 1        | 2013 | 31.95a           | 17.28b            | 45.65a            | 17.80a                           | 7.30ab                     | 42.90a         |
|            | 2014 | 31.70a           | 17.40a            | 45.51ab           | 17.65a                           | 7.31a                      | 41.40a         |
| T 2        | 2013 | 32.75a           | 18.02a            | 46.32a            | 17.65a                           | 7.80a                      | 44.77a         |
|            | 2014 | 32.20a           | 17.30a            | 46.20a            | 17.80a                           | 7.57a                      | 42.80a         |
| T 3        | 2013 | 31.00a           | 16.80c            | 44.30a            | 16.80b                           | 7.20ab                     | 41.01a         |
|            | 2014 | 31.50ab          | 17.6a             | 45.50b            | 17.60a                           | 7.55a                      | 42.80a         |
| T 4        | 2013 | 27.75b           | 16.76c            | 43.37a            | 16.74b                           | 6.87b                      | 41.00a         |
|            | 2014 | 30.60b           | 16.80a            | 44.30c            | 16.88b                           | 6.51a                      | 38.59a         |

Means in columns followed by the same letter are not significantly different at \(P = 0.05\).
Abbreviations: T1, T2, T3 and T4 are herbicide dose 0.5, 0.3, 0.2 L/ha\(^{-1}\) plus bio-agents and control respectively.
reduction was obtained with herbicide rate 0.3 kg/ha\(^{-1}\) in combined to bio-agents that were close to results with its labeled rate.

In this regard, reducing herbicide rate seem to recommend a desirable weed management technique to diminish chemical consumption across the globe\(^{39,38}\). Registration of herbicide doses are set at a level designed to provide high weed mortality across a range of environmental status\(^{65}\). On the other hand, using herbicides at below labeled rate is risky because herbicide efficacy depends strongly on competitive ability of host plant, herbicide efficiency and the crop growth stage\(^{17}\).

### 3.3.1 Agronomical Efficiency

As it is obvious, the most efficient treatment was verdict 0.3 kg/ha\(^{-1}\) in integrated with bio-agent about all three experimental years (Table 3). When herbicides applied at proper rates, obtain favorable weed reduction with no crop damage. Reducing the dose of chemical is going to be an appropriate technique. Thus, labeled doses of chemicals are always defined to ensure higher control of spectrum of weed species and growth stages\(^{8,22}\). In this regards, herbicide concentration can be different and might be diminished regarding to the density of weeds and environmental factors. Several scientific findings indicate that favorable weed management can be achieved when chemicals are applied at low herbicide rates\(^{31,33,66-68}\).

### 3.3.2 Energetic Efficiency

Energetic efficiency is an important factor for sustainability of the cropping systems, hence, effective energy use allows financial savings\(^{85}\) and can lead to environment-friendly production systems\(^{22,23}\). For the mentioned reason, energy input and output are essential option to specify the energetic efficiency of crop productions\(^{31}\). Present study indicated that the best energy output was obtained (90.3 GDj/ha\(^{-1}\)) when intermediate verdict rate 0.3 kg/ha\(^{-1}\) plus bio-component was done (Table 4).

| Treatments | Yield t/ha\(^{-1}\) | Average Yield enhancement | % |
|------------|----------------|---------------------------|---|
| 2012       | 2013           | 2014                      |
| T 1        | 5.8            | 7.3                       | 7.8 | 6.97 | 0.80 | 13.0 |
| T 2        | 6.5            | 7.7                       | 7.9 | 7.40 | 1.23 | 19.9 |
| T 3        | 5.8            | 7.2                       | 7.5 | 6.83 | 0.66 | 10.7 |
| T 4        | 5.2            | 6.8                       | 6.5 | 6.17 | -    | -    |
| HCP\(_{av}\) | 0.23          | 0.18                      | 0.21 |     |      |      |

Abbreviations: T1, T2, T3 and T4 are herbicide dose 0.5, 0.3, 0.2 L/ha\(^{-1}\) plus bio-agents and control respectively.

| Treatments | Yield, t/ha | Energy output, GDj/ha\(^{-1}\) | Cost, GDj/ha | Energetic efficiency rate |
|------------|-------------|-------------------------------|--------------|--------------------------|
| T 1        | 6.97        | 85.0                          | 10.0         | 1.7                      |
| T 2        | 7.40        | 90.3                          | 10.7         | 1.8                      |
| T 3        | 6.83        | 83.3                          | 9.8          | 1.7                      |
| T 4        | 6.17        | 75.3                          | 8.9          | 1.8                      |

Abbreviations: T1, T2, T3 and T4 are herbicide dose 0.5, 0.3, 0.2 L/ha\(^{-1}\) plus bio-agents and control respectively.

### 4. Conclusion

This study illustrated that herbicides at lower than labeled dose can also result desirable weed reduction. It can be resulted, that verdict use at a reduced rate, and combined to biological components caused an adequate weed suppression efficacy, without diminish in crops. Results of 3-yrs experiments indicated that a desirable level of weed reduction was obtained when lower concentration of herbicide rate 0.3 kg/ha\(^{-1}\) plus bio-agents. This approach can be operated as an economically effective technique and environmental-friendly practice to diminish weed damage.

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