# Exogenous Methyl Jasmonate Regulates Photosystem II Efficiency and Metabolic Reprogramming Under Terminal Heat Stress in *Brassica juncea* L.

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## Introduction

During summer season in North Indian Plains, the temperature rises to almost 40 to 45°C and the terminal grain or pod filling stages of rabi crops is severely affected.

In oilseed mustard, heat stress at the post-anthesis (seed-filling) stage has a detrimental effect on photosynthate transport to growing sinks, which in turn lowers oil content and seed yield.

Chlorophyll fluorescence parameter analysis are crucial indicators for assessing the condition or integrity of the internal machinery during the photosynthetic process within a leaf. It also offers a quick and precise way to identify and measure a plant's stress tolerance (Jat *et al.*, 2024).

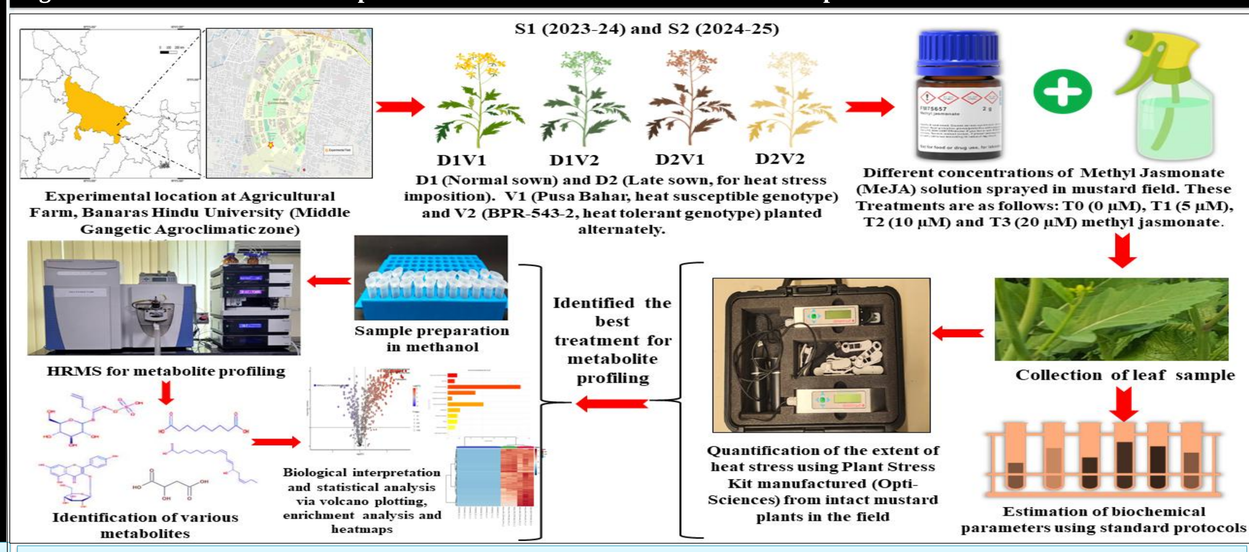
Methyl jasmonate (MeJA), a volatile methyl ester of jasmonic acid hormone, has been shown to mitigate heat stress in mustard by improving chlorophyll fluorescence parameters and photosynthetic traits. MeJA decreased the oxidative damage brought on by terminal heat stress and enhanced the activity of antioxidant enzymes in various crops.

Metabolic profiling via HRMS, chlorophyll fluorescence parameter analysis and biochemical quantification are crucial indicators for assessing the condition or integrity of the internal machinery within a leaf. It also offers a quick and precise way to identify and measure a plant's stress tolerance (Jat et al., 2024).

Thus, by assessing different chlorophyll fluorescence parameters, physiological parameters, pollen viability and metabolites the extent of terminal stress on contrasting mustard genotypes and methyl jasmonate treatment ameliorative effects in devising potential heat stress mitigating solutions can be determined.

## Material and Methods

**Figure 1: The flowchart of the experimental materials and methods that were performed across two seasons**




## Results and Discussion

**Figure 2: The effect of foliar spray of different concentrations of methyl jasmonate on pollen viability of contrasting mustard genotypes grown under heat stress regimes**

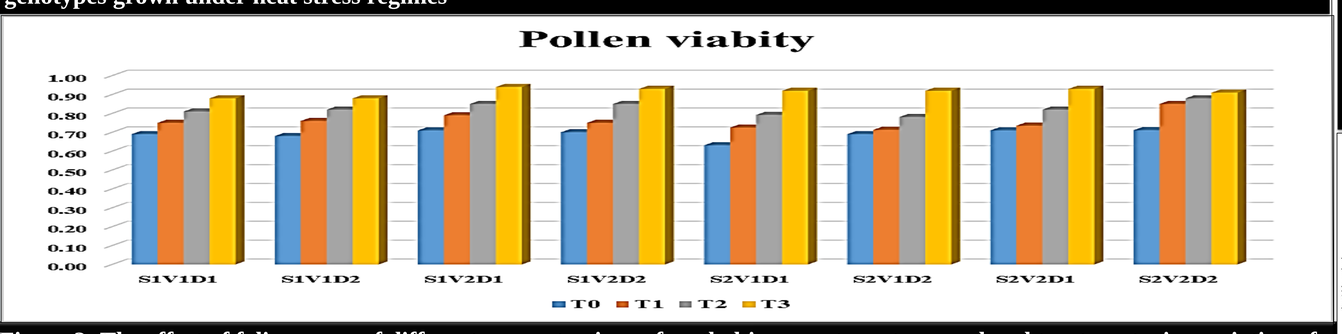



**Figure 2: The effect of foliar spray of different concentrations of methyl jasmonate on temporal and treatment wise variation of various physiological parameters in contrasting mustard genotypes grown under heat stress regimes.**

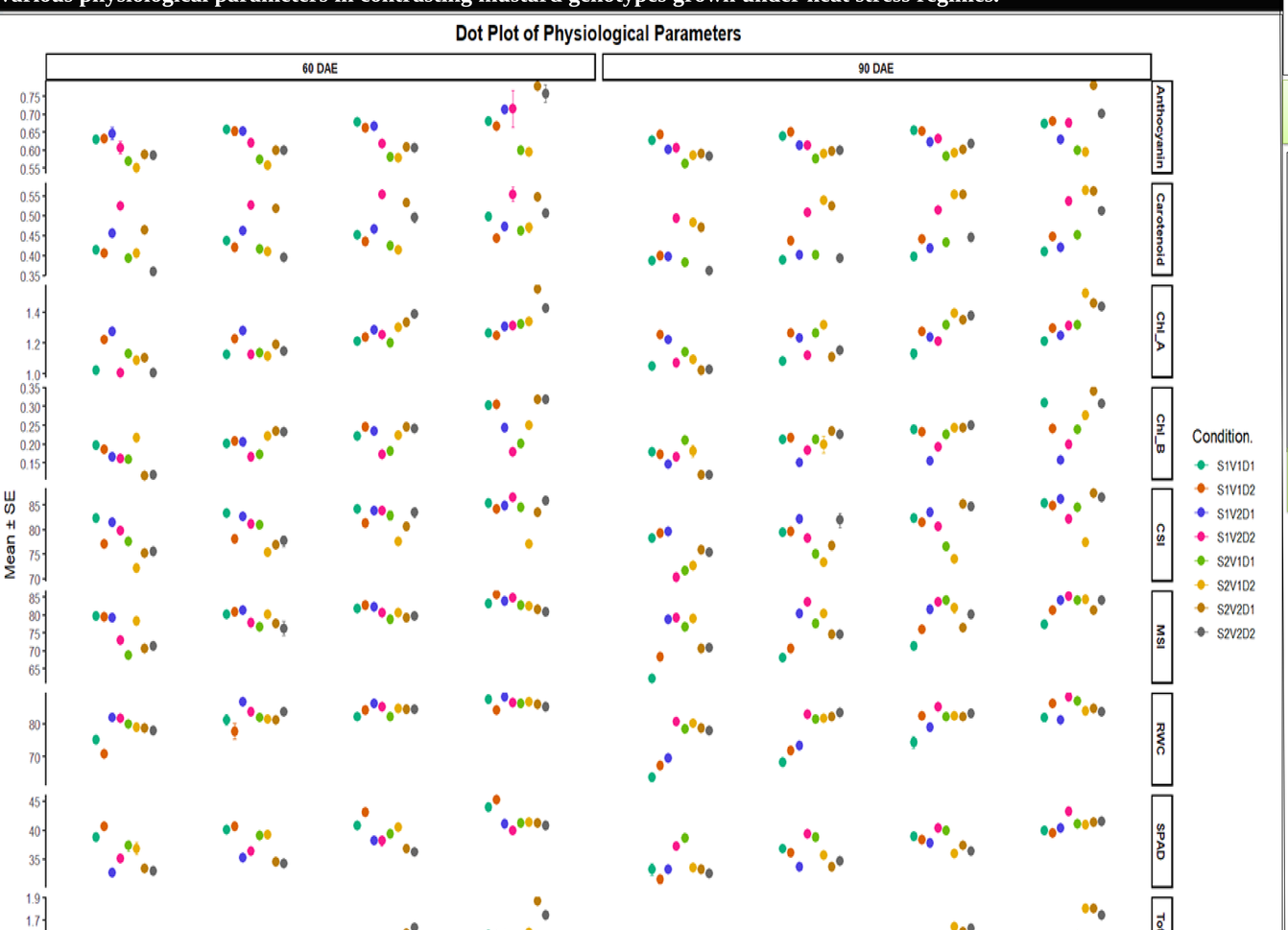
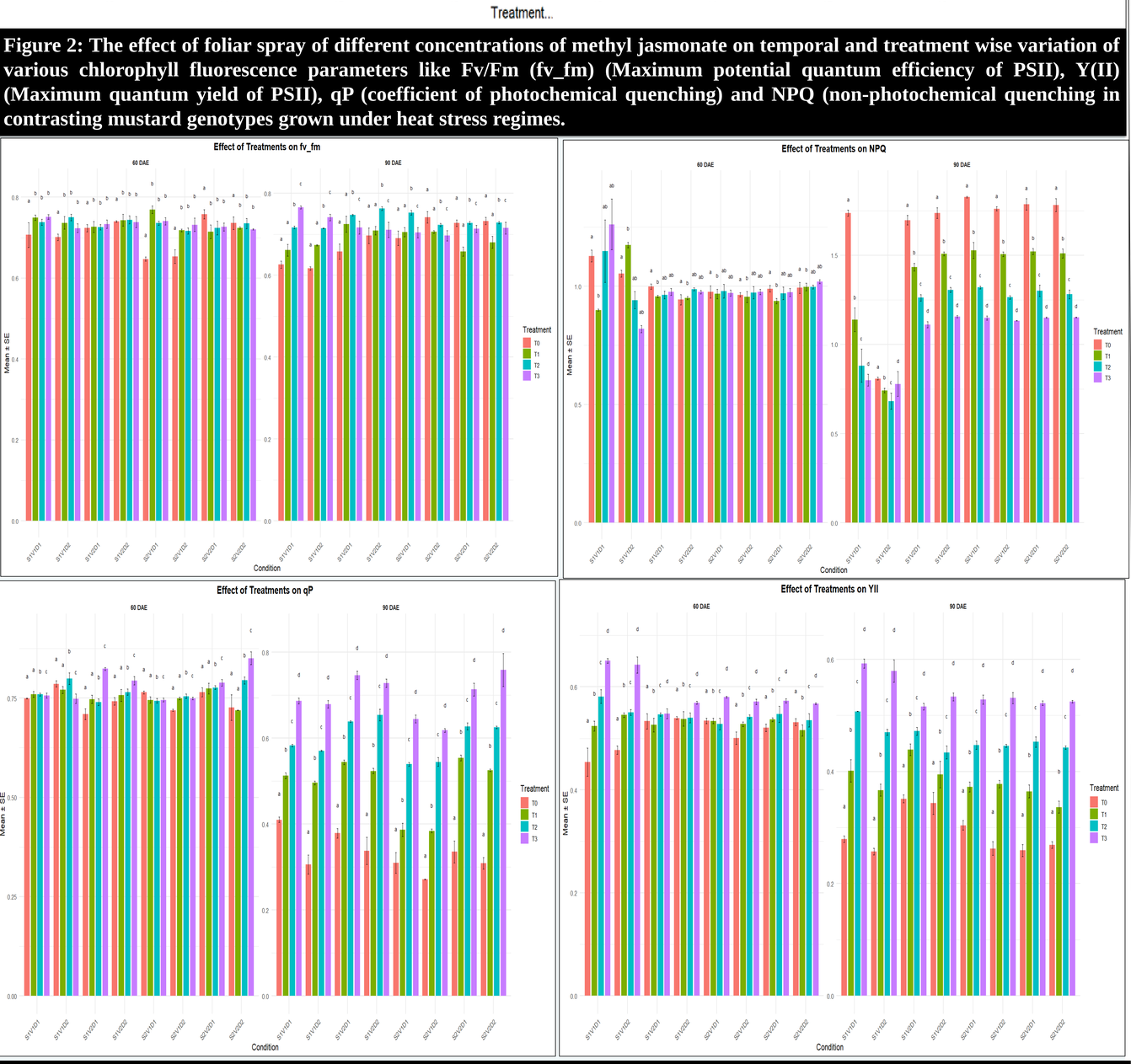


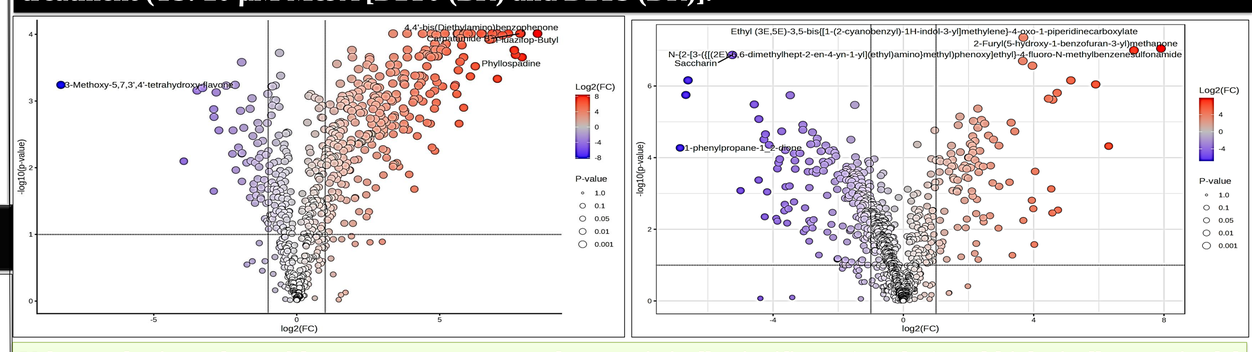

**Figure 2: The effect of foliar spray of different concentrations of methyl jasmonate on temporal and treatment wise variation of various chlorophyll fluorescence parameters like Fv/Fm (fv_fm) (Maximum potential quantum efficiency of PSII), Y(II) (Maximum quantum yield of PSII), qP (coefficient of photochemical quenching) and NPQ (non-photochemical quenching in contrasting mustard genotypes grown under heat stress regimes.**



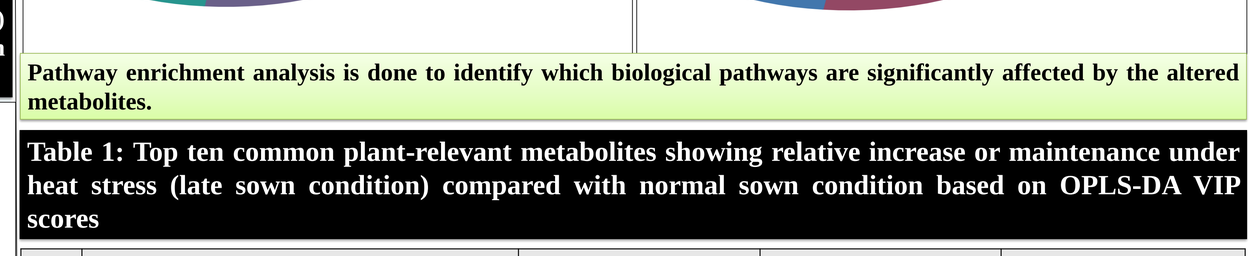

**These findings highlight the potential of incorporating biochemistry and chlorophyll fluorescence-based screening into precision breeding and crop management strategies under climate change, and they provide strong biological evidence in favor of the use of methyl jasmonate (T3; 20 µM) in heat stress amelioration.**

## Results and Discussion (contd…)

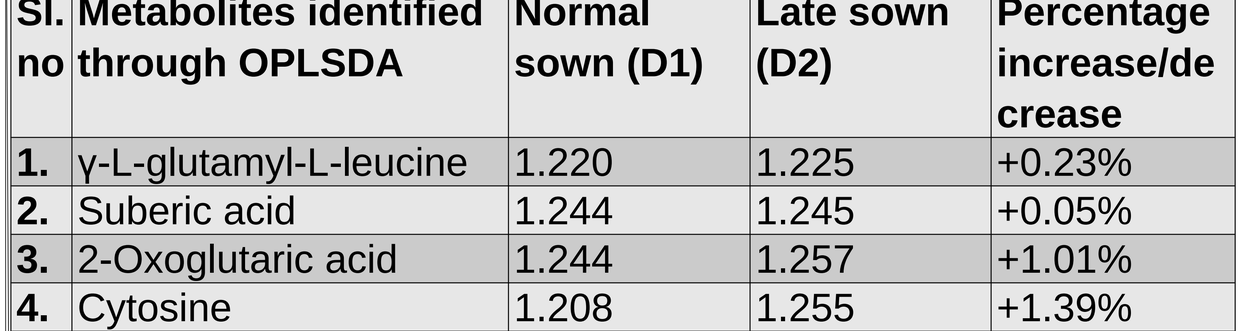
**Figure 3: Metabolite profiling via HRMS done to establish how the heat susceptible variety (V1; Pusa Bahar) is performing in timely sown condition (D1) under control (T0: 0 µM MeJA) and best treatment (T3: 20 µM MeJA) [D1T0 (AR) and D1T3 (CR)] against how the susceptible variety (V1; Pusa Bahar) is performing in heat stress condition (D2) under control (T0: 0 µM MeJA) and best treatment (T3: 20 µM MeJA [D2T0 (BR) and D2T3 (DR)].**



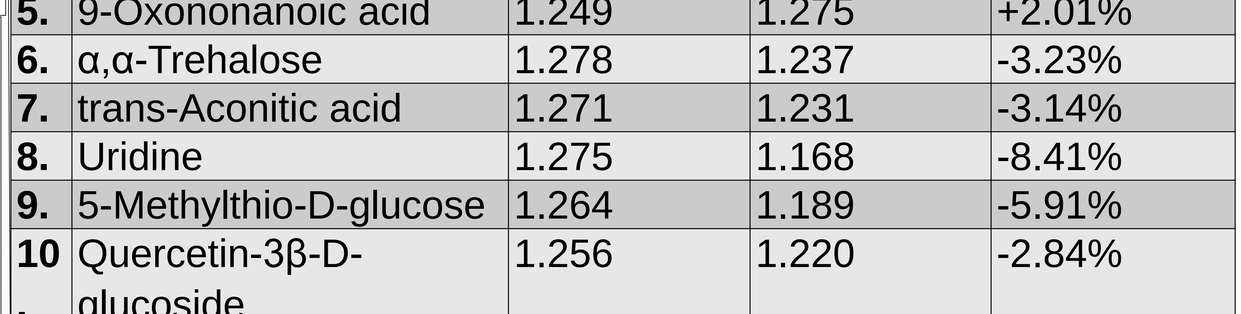

**Volcano plot is performed between two groups to show statistically significant (p-value) and biologically meaningful differences**




**PCA is performed to visualize overall variation in the metabolomics dataset of two groups and identify natural clustering or separation of samples**




**Top 15 annotated metabolites with variable importance at x-axis**




**Pathway enrichment analysis is done to identify which biological pathways are significantly affected by the altered metabolites.**

**Table 1: Top ten common plant-relevant metabolites showing relative increase or maintenance under heat stress (late sown condition) compared with normal sown condition based on OPLS-DA VIP scores**

| Sl. no | Metabolites identified through OPLSDA | Normal sown (D1) | Late sown (D2) | Percentage increase/decrease |
|---|---|---|---|---|
| 1. | γ-L-glutamyl-L-leucine | 1.220 | 1.225 | +0.23% |
| 2. | Suberic acid | 1.244 | 1.245 | +0.05% |
| 3. | 2-Oxoglutaric acid | 1.244 | 1.257 | +1.01% |
| 4. | Cytosine | 1.208 | 1.255 | +1.39% |
| 5. | 9-Oxononanoic acid | 1.249 | 1.275 | +2.01% |
| 6. | α,α-Trehalose | 1.278 | 1.237 | -3.23% |
| 7. | trans-Aconitic acid | 1.271 | 1.231 | -3.14% |
| 8. | Uridine | 1.275 | 1.168 | -8.41% |
| 9. | 5-Methylthio-D-glucose | 1.264 | 1.189 | -5.91% |
| 10. | Quercetin-3β-D-glucoside | 1.256 | 1.220 | -2.84% |

## Conclusions and Future Perspectives

**Integrated biochemical and photochemical analyses identified the most effective treatment for heat stress mitigation in mustard, and subsequent metabolite profiling revealed treatment-driven metabolic reprogramming that restores stress-sensitive pathways in the susceptible variety under heat stress. The same metabolite profiling methods can be done for the heat tolerant genotypes to identify the biomarkers that are responsible for heat tolerance under best treatment compared to control.**

## References

- Jat, M., Ray, M., Ahmad, M. A., & Prakash, P. (2024). Unravelling the photosynthetic dynamics and fluorescence parameters under ameliorative effects of 24-epibrassinolide in wheat (Triticum aestivum L.) grown under heat stress regime. Scientific Reports, 14(1), 30745. https://doi.org/10.1038/s41598-024-79676-6